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GEOLOGY AND MINERAL AND HYDROCARBON POTENTIAL OF NORTHERN YUKON TERRITORY AND NORTHWESTERN DISTRICT OF MACKENZIE

Edited by

D.K. Norris

1997

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CHAPTER 1

INTRODUCTION

D.K. Norris

Norris, D.K., 1996. Introduction. In The Geology, Mineral and Hydrocarbon Potential of Northern Yukon Territory and Northwestern District of Mackenzie. Geological Survey of Canada, Bulletin 422, p. 1–5.

HISTORICAL BACKGROUND

In 1952 the Geological Survey of Canada undertook the first systematic mapping of one of the more remote regions of northern Canada using helicopters. The trial project, Operation Keewatin, set the stage for a series of successful reconnaissance mapping endeavors covering vast regions of the Canadian Shield, the Arctic Islands, and the northern Canadian Cordillera and adjacent Interior Plains.

Operation Porcupine was one of these air-supported projects. It was conceived by the late J.M. Harrison, then Director of the Geological Survey, and the late C.S. Lord, then Chief Geologist. As geologist-in-charge, I formulated the plan of operations and coordinated the various activities of several research scientists involved in the project (see Norris, 1963). Operation Porcupine was the start of a succession of continuing field and laboratory studies in the northern Cordillera. The area has proved to be much more complex than was initially anticipated. By reason of its complexity, however, it has proved to hold the keys to a better understanding of the processes of orogenesis, epeirogenesis, mineralization and hydrocarbon entrapment; not only here but in mountain belts around the world.

The project was formally initiated on April 26, 1961, upon receipt of field instructions from Harrison and Lord. They were as follows: "Your main field work for the summer of 1961 will be a preliminary reconnaissance of the Operation Porcupine area (65°N to Beaufort Sea; 132°W to 141°W; Yukon and Northwest Territories). The object of this reconnaissance is to confirm the feasibility of your plan of operations for Operation Porcupine in 1962, the precise location of principal gas caches and base camps, and the location of critical stratigraphic sections identified by an office study of aerial photographs" (Geological Survey of Canada, 1961, Internal Memorandum, Field Instructions to D.K. Norris).

THE PROJECT AREA

The area encompassed by Operation Porcupine was that part of Yukon Territory and Northwest Territories north of latitude 65°N and west of longitude 132°W (Fig. 1.1). It embraced approximately 207 000 km^2 (80 000 sq. mi.), and included parts of Peel and Anderson Plains, Peel Plateau, Yukon Coastal Lowland, British, Barn, White, Richardson, Mackenzie, Wernecke and Ogilvie Mountains, Keele and Old Crow Ranges, and Old Crow and Eagle Plains (Fig. 2.1).

There are few lakes west of the Richardson Mountains and Mackenzie Delta suitable for use with float-equipped aircraft. Hungry, Margaret, Horn, and Whitefish lakes (Fig. 1.1) proved invaluable, not only because of their position with respect to bedrock and surficial geology but also because they were large enough, under suitable conditions, for ski-equipped DC-3 and twin-engine Otter aircraft to land. On Peel Plateau, and Peel and Anderson plains, landing sites for fixed-wing aircraft were abundant, both on lakes and on major rivers. On the other hand, at that time, a large area of the northern Ogilvie Mountains, Keele Range, and Eagle and Old Crow plains was only accessible from a camp on Porcupine River, approximately on the Arctic Circle (Fig. 1.1). All aircraft fuel for that camp had to be ferried by helicopter and inflatable boat from a winter airstrip. The Dempster Highway[1], connecting Dawson City and Inuvik, was years away from being constructed.

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[1] The Dempster Highway was conceived in the 1950's under the Federal Government's Roads to Resources Program to encourage the economic development of the Yukon and Northwest Territories. It was named after Corporal W.J.D. Dempster of the Royal Northwest Mounted Police and was opened officially in 1979. It is the only public road in North America to cross the Frontal Belt of the Cordilleran Orogen at the latitude of the Arctic Circle.

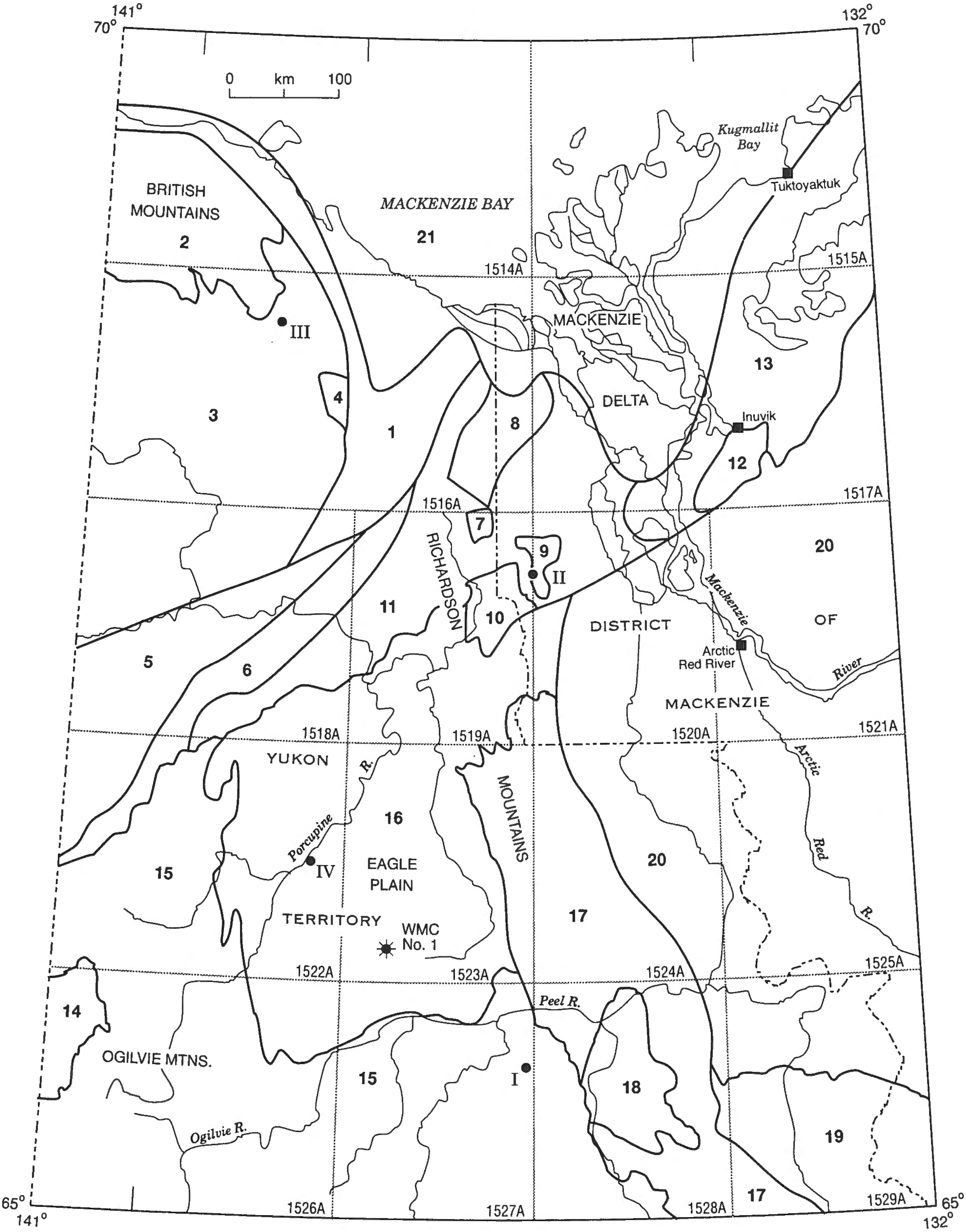

Figure 1.1. *Location map showing the geographic limits of the project area, the twenty-one tectonic elements embraced within it (see Chapter 3, this volume), the location of the four base camps numbered in order of occupancy (I, Hungry Lake; II, Horn Lake; III, Babbage River; IV, Porcupine River), Western Minerals Chance No. 1 wellsite (WMC No. 1), and the disposition of the sixteen 1:250 000 scale published reconnaissance geological maps of the region.*

PERSONNEL AND AREAS OF RESPONSIBILITY

The success of the 1962 operation was the result of the combined efforts of nine Survey geologists and a supporting crew of 21. The geologists were E.W. Bamber, O.L. Hughes, E.W. Mountjoy, B.S. Norford, A.W. Norris, D.K. Norris, R.A. Price, R.M. Procter and G.C. Taylor. The supporting crew comprised three technical officers (A.J. Jenik, V. Rampton and G.R. Turnquist), nine student assistants (N.L. Ball, W.J. Clack, D. Jordan, W. Kisluk, D. Mayes, D.A. McAuslan, J.K. Potts, U. Upitis, and D. Wetter), one radio operator (W. Warren), two cooks (O. Gunderson and I. Sundquist), five aircrew and one expediter in Dawson City.

The areas of responsibility of the Survey geologists during this operation in 1962 were as follows: E.W. Bamber, Carboniferous and Permian stratigraphy and paleontology; O.L. Hughes, Pleistocene geology and Holocene geomorphology; E.W. Mountjoy, Mesozoic and Tertiary stratigraphy; A.W. Norris, Devonian stratigraphy and paleontology; B.S. Norford, Ordovician and Silurian stratigraphy and paleontology; R.A. Price, regional structural geology; R.M. Procter, Precambrian and Cambrian stratigraphy; G.C. Taylor, intrusive rocks and regional structural geology; and D.K. Norris (geologist-in-charge), management and coordination of scientific activities undertaken during the operation, regional structural geology and regional tectonic synthesis.

PREPARATIONS

In the spring of 1961, a preliminary assessment of all available geological information was made. Of primary concern was the feasibility of completing a reconnaissance map of the bedrock and surficial deposits in one field season, if it could be assumed that average weather conditions would be encountered and that the snowfall in the area would not be abnormally heavy during the winter of 1961–62.

A DeHavilland Beaver was chartered from Connelly-Dawson Airways from July 4 to 8, 1961, and a flight was made over much of the project area on a prescribed flight line. Many localities and potentially important stratigraphic sections critical to the interpretation of the geology of the region were observed from the air. Potential base camp and gas cache sites were visited and their locations marked on air photographs to be used the following winter during the caching operations.

This overflight made it apparent that: 1) a reconnaissance geological survey of the area could be completed in one field season if snow and weather conditions were at all reasonable; 2) the amount of geological work required to complete a study of the south half of the area would be about the same as for the north half, in spite of the continuous exposure of carbonates and clastics south of the Arctic Circle and the dominance of recessive weathering clastics north of it; and 3) Dawson City should be used as a source of supplies because it was connected by road with Whitehorse and Edmonton, and was a terminus of Canadian National Telegraphs.

During the winter of 1961–62 regional geological maps were compiled on a scale of eight miles to one inch from all available public information on the stratigraphy and structure of the area. These proved invaluable in orienting stratigraphers and structural geologists alike in the course of their field studies. Vertical air photographs were used to prepare preliminary photo-geological maps on a scale of two miles to the inch, consistent with the eight-mile maps in hand. It was not possible to complete all the maps prior to the 1962 field season, partly because of the difficulty of differentiating middle and upper Paleozoic rocks from Mesozoic formations in the north half of the area and partly because some structural problems could only be resolved after checks were made on the ground. Many stratigraphic contacts selected prior to establishing ground control, however, proved to be formational contacts for the 1:250 000 scale geological maps.

The thickness, stratigraphic range and known ages for approximately 100 sections were catalogued according to NTS map area and location (Appendix I).

Prior to the field operations in 1962, each of the catalogued sections was assigned to one of the stratigraphers. In this manner stratigraphic studies could be divided more evenly among the scientists involved. Specialists in one part of the stratigraphic column measured and studied sections of interest to others in areas where their particular rock sequence was absent or not very extensive.

Duplicate air photographs were obtained for all of the sections anticipated to be studied so that the stratigraphers and structural geologists each had their own set of pictures. In this way they could collaborate in the mapping process.

The Hiller 12E helicopter and the DeHavilland Beaver were chosen for the operation. The 12E was capable of setting out a two-person fly camp with a week's supplies in one flight, or enabling two geologists to traverse simultaneously. Sitting on either side of the pilot, they could discuss with one another what they observed by means of a two-way communication system. The float-equipped Beaver readily handled fly camp set outs along the major rivers and weekly supply trips to Dawson City. For camp moves, however, additional fixed-wing aircraft were called upon in order that the moves could be completed as quickly as possible. This was essential in view of the unpredictability of the weather in that region. A DC-3 aircraft was used for transportation of personnel and supplies in the initial stages of the operation.

Klondike Helicopters Ltd., Whitehorse, supplied the two Hiller 12E helicopters and Connelly-Dawson Airways Ltd., Dawson City, the Beaver. Connelly-Dawson Airways also supplied an additional Beaver and a Grumman Widgeon for camp moves.

Gas caching was carried out during the first three weeks of April, 1962, under the direction of G.C. Taylor. The base camp and gas cache sites on Hungry (I) and Horn (II) lakes, and on an unnamed lake west of Babbage River (III), presented no problems (see Fig. 1.1). For the camp on Porcupine River (IV), on the other hand, it was necessary to prepare a winter airstrip on a flat stretch of ground immediately east of Whitestone River and about 30 km south of the Porcupine River camp. Arrangements were made to use equipment at the Western Minerals Chance No. 1 well site in southern Eagle Plain (Fig. 1.1) to prepare the strip.

SCHEDULE OF THE OPERATION

Personnel and equipment were moved by DC-3 to an airstrip prepared by the California Standard Company near the mouth of Blackstone River between May 13 and 17, 1962. From there they went 65 km east by ski-equipped Beaver aircraft to the first base camp on the north shore of Hungry Lake. Thin ice with several centimetres of water on top made conditions on the lake unsuitable for the DC-3. It was necessary to offload the Beaver some distance from shore and drag equipment to high ground on makeshift toboggans.

With the arrival of the helicopters on May 20, stratigraphers and paleontologists proceeded immediately with nearby day set outs for the first week and with regular fly camps farther afield thereafter. Most of the south-facing slopes were largely free of snow by that time so that mapping by helicopter went ahead as time permitted.

Excellent weather prevailed for the first month. During break-up period on Hungry Lake, regular supply trips were made by helicopter to the Blackstone River airstrip where a rendezvous was made with the Beaver. Camp moves were usually completed in one to two days. However, in early August, a combination of bad weather, shortening of twilight hours, and major mechanical breakdowns of one of the helicopters and one of the Beavers resulted in the move to the final base camp (IV) on Porcupine River being spread over about 5 days.

After August 15 the weather began to deteriorate, and by August 31 reached the point where snow and winter temperatures prevailed. At that time most primary objectives of the operation had been met and personnel and equipment were moved to Dawson City by September 3.

During the 1962 field season 108 days were spent in the project area. A total of 526 hours were flown with the Beaver, 17 hours with the Widgeon, and 791 hours with the two helicopters.

ACCOMPLISHMENTS[1]

The information gathered during the 1962 field season was first published as a simplified bedrock geological map (Norris et al., 1963) at a scale of 1:1 000 000. This map was followed by a succession of other maps and reports dealing with the stratigraphy, paleontology, structure and Quaternary geology. A map of the surficial geology at a scale of 1:500 000 was published by Hughes (1972). The bedrock geological map revealed the distribution of rock units in the project area, and the relationship of these units in a hitherto unmapped region to those adjoining them in northern Mackenzie Mountains and in northeastern Alaska.

It became apparent that much additional data would be required to complete the mapping of both the bedrock and surficial deposits in the area at a scale of 1:250 000. These data were essential, not only because of a growing interest in the hydrocarbon potential of Eagle Plain, Peel Plateau, Mackenzie Delta and the continental shelf of southern Beaufort Sea, but also because of the prospects for building an all-weather road connecting Inuvik with the Klondike Highway and Dawson City, and for a pipeline from Prudhoe Bay, Alaska to the Mackenzie Valley.

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[1] When acknowledging, reference should be made to individual authors by chapter and page number.

Follow-up investigations began immediately. In 1963, E.W. Bamber extended his biostratigraphic studies of upper Paleozoic formations; in 1968, D.K. Norris continued his regional structural studies; in 1970, L.D. Dyke began investigating the structural fabric of selected uplifts in the northern part of the area and F.G. Young initiated studies of the stratigraphy of the Upper Cretaceous and Tertiary rocks northwest of the Mackenzie Delta; in 1973, W.H. Fritz documented the physical stratigraphy and biostratigraphy of the Cambrian System; in 1975, T.P. Poulton began his investigations of the physical stratigraphy and biostratigraphy of the Jurassic System; in 1979, J. Dixon extended studies of the physical stratigraphy of the Upper Cretaceous and Tertiary rocks of the lower Mackenzie River Basin and continental shelf; and in 1982, B.D. Ricketts described and interpreted the stratigraphy and sedimentology of Upper Cretaceous rocks at the headwaters of the Ogilvie River. In addition, within the past decade, the work of F.A. Cook, K.C. Coflin (University of Calgary) and J.R. Dietrich has greatly increased our understanding of both the shallow and deep seismic stratigraphy and structure beneath Mackenzie Delta and the continental shelf of southern Beaufort Sea. The numerous publications by all the above named are referenced in the fourteen chapters that follow and should make this volume an up-to-date statement of the geology, and mineral and hydrocarbon potential of the region.

Acknowledgments

Many oil, mining and consulting companies have pioneered the geological assessment of the region. They have shared generously their knowledge and experiences with the Geological Survey and have spared all who participated in this project some of the frustrations that go with carrying out field programs in such a climatically hostile and unforgiving environment. Technical Officers Jenik, Rampton and Turnquist made invaluable contributions to our understanding of the stratigraphy and structure of the region through their examination of outcrops inaccessible by helicopter, from inflatable boats along many of the major rivers. Student assistants Mayes and Upitis helped considerably by providing additional stratigraphic and paleontological data from sections intermediate among the basic network of control points established by the geologists for the region.

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1972: Surficial geology of northern Yukon Territory and northwestern District of Mackenzie, Northwest Territories. Geological Survey of Canada, Paper 69-36 (Report and Map 1319A), 11 p.

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1963: Light helicopter reconnaissance, Operation Porcupine, 1962. Canadian Mining Journal, v. 84, p. 45-50.

Norris, D.K., Price, R.A., and Mountjoy, E.W.
1963: Geology, northern Yukon Territory and northwestern District of Mackenzie. Geological Survey of Canada, Map 10-1963, scale 1:1 000 000.

Yukon Coastal Lowland southwest of Herschel Island, Y.T. GSC photo 11.2125B

CHAPTER 2

PHYSIOGRAPHIC SETTING

D.K. Norris

Norris, D.K., 1996. Physiographic setting. In The Geology, Mineral and Hydrocarbon Potential of Northern Yukon Territory and Northwestern District of Mackenzie. Geological Survey of Canada, Bulletin 422, p. 7–20.

Abstract

The project area is contained within four physiographic regions: the Cordillera, Interior Plains, Arctic Coastal Plain and Arctic Continental Shelf. Elevations range from -200 m at the outer edge of the shelf to greater than 2 km in the Mackenzie Mountains of the Cordillera. Each of the regions is made up of one or more divisions that correspond in whole or in part to the basic tectonic elements, implying an inherent, underlying structural and stratigraphic control. The area lies entirely within the zone of continuous permafrost. In the Cordilleran Region, the Wernecke and southern Ogilvie Mountains underwent repeated montane glaciation whereas other areas such as the Old Crow Flats and Pediplain were never glaciated. The Late Wisconsinan Laurentide ice sheet, on the other hand, covered the Interior Plains and Arctic Coastal Plain, including the continental shelf. It played a major role in blocking and temporarily redirecting the eastward flow of some of the major rivers draining the northern Cordillera.

Résumé

La région à l'étude couvre quatre régions physiographiques : la Cordillère, les Plaines intérieures, la plaine côtière de l'Arctique et la plate-forme continentale de l'Arctique. Les altitudes varient de -200 m, au rebord extérieur de la plate-forme continentale, à plus de 2 km dans les monts Mackenzie dans la Cordillère. Chaque région est composée d'une ou de plusieurs divisions qui correspondent en tout ou en partie aux éléments tectoniques de base, ce qui sous-entend un contrôle structural et stratigraphique sous-jacent inhérent. La région se situe entièrement dans la zone de pergélisol continu. Dans la région de la Cordillère, les monts Wernecke et les monts Ogilvie méridionaux ont subi des glaciations répétées tandis que d'autres régions comme la plaine et la pédiplaine d'Old Crow n'ont jamais été englacées. L'Inlandsis laurentidien du Wisconsinien supérieur, par ailleurs, a recouvert les Plaines intérieures et la plaine côtière de l'Arctique, incluant la plate-forme continentale. Il a joué un rôle majeur en bloquant et en redirigeant temporairement l'écoulement vers l'est de certains cours d'eau importants drainant la Cordillère septentrionale.

INTRODUCTION

The project area is contained within four physiographic regions of northwestern Canada: the Cordillera, Interior Plains, Arctic Coastal Plain, and Arctic Continental Shelf (Bostock, 1948; Mathews, 1986; Table 2.1). All four overlap the boundary between Yukon Territory and Northwest Territories to varying degrees. Each of the regions, in turn, is made up of one or more divisions that correspond in whole or in part to tectonic elements or subelements comprising the Frontal Belt of the northern Cordillera and contiguous Interior Platform (Norris, 1983).

The physiographic divisions, like their tectonic counterparts, possess an inherent structural and lithologic control: deformed and truncated, older, erosionally resistant formations tend to form mountain ranges, and relatively undeformed, younger, less resistant formations, plateaux and plains. Thus, the divisions, like their tectonic counterparts, may overlap or interrupt one another. They lack the great linearity and parallelism of divisions in equivalent structural positions in the Frontal Belt of southern Canada, tend to be more equidimensional and, where linear, tend to strike in a variety of directions (Fig. 2.1).

Table 2.1

Physiographic regions and divisions* and their corresponding tectonic elements

Region	Composite Unit	Division	Tectonic Element
Cordillera	Arctic Mts.	British Mts.	Romanzof Uplift
		Barn Mts.	Barn Uplift
		Old Crow Pediplain	Old Crow–Babbage Depression
		Old Crow Flats	Old Crow–Babbage Depression
		Old Crow Range	Old Crow–Babbage Depression
		Keele Range	Aklavik Arch Complex
		Dave Lord Range	Aklavik Arch Complex
		Eagle Lowland	Eagle Foldbelt
		Northern Richardson Mts.	Aklavik Arch Complex
		Southern Richardson Mts.	Richardson Anticlinorium
		Bonnet Plume Depression	Bonnet Plume Basin
	Ogilvie Mts.	Northern Ogilvie Mts.	Taiga–Nahoni Foldbelt
		Southern Ogilvie Mts.	Taiga–Nahoni Foldbelt
	Selwyn Mts.	Wernecke Mts.	Taiga–Nahoni Foldbelt
	Mackenzie Mts.	Backbone Ranges	Mackenzie Foldbelt
		Canyon Ranges	Mackenzie Foldbelt
Interior Plains	—	Peel Plateau	Northern Interior Platform
		Peel Plain	Northern Interior Platform
		Anderson Plain	Northern Interior Platform
Arctic Coastal Plain	—	Yukon Coastal Lowland	Rapid Depression
		Mackenzie Delta	Aklavik Arch Complex
Arctic Continental Shelf	—	Mackenzie Shelf	Beaufort Shelf

*after Bostock (1948) and Mathews (1986)

The boundaries between physiographic divisions and between tectonic elements may be arbitrary and need not correspond exactly because different criteria were used to define them. Thus, from a physiographic point of view, Ogilvie Mountains are divided into two parts at the headwaters of Ogilvie River (Mathews, 1986), whereas stratigraphic continuity within the Phanerozoic rock succession requires a single tectonic element, the Taiga–Nahoni Foldbelt (Norris, 1983). Moreover, Quaternary physiographic divisions, such as the Yukon Coastal Lowland and Mackenzie Delta, cut across mid-Eocene and older elements, such as the Romanzof Uplift, Rapid Depression and Aklavik Arch Complex, with little regard for structure. In addition, the continuation of the boundary between Canyon and Backbone Ranges of Mackenzie Mountains in the southeast corner of the project area appears to be arbitrary.

Elevations in the project area range from about -200 m at the outer edge of the continental shelf to greater than 2 km in Mackenzie Mountains. In the Interior Plains, elevations of 800 m are common adjacent to Mackenzie Mountains, but decrease progressively northward to 30 m at the upper end of Mackenzie Delta.

Except for the west–central part of the project area, there is trimetrogon air photo coverage of the landscape. The pictures, mostly taken during the Second World War, reveal the physiography in startling detail. For many years, these pictures were the only record of this vast, relatively unexplored region. They were the basis for the pioneering work of H.S. Bostock in his analysis of the Cordillera north of the fifty-fifth parallel (Bostock, 1948). Some of the photographs he used are included here, supplemented

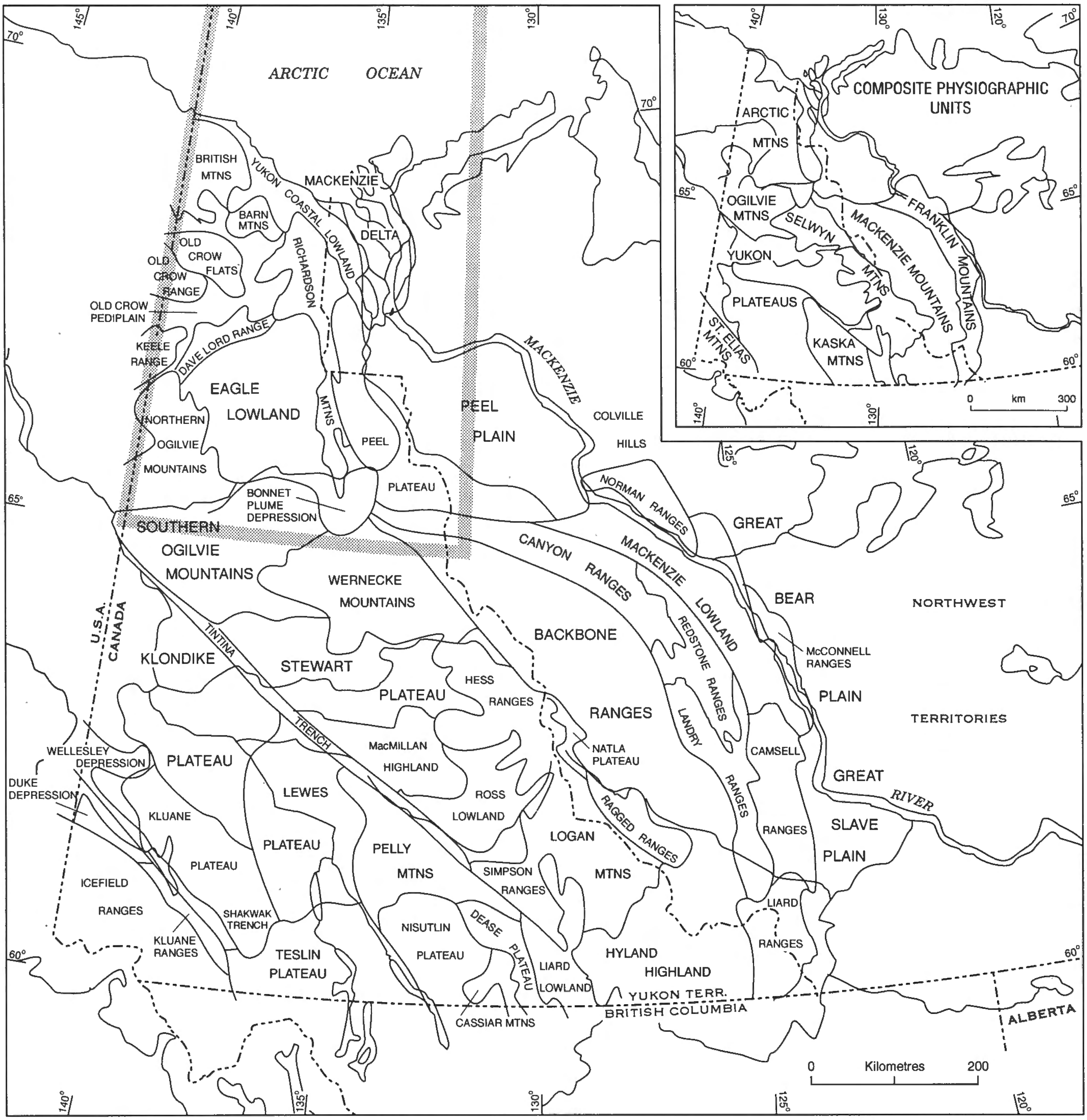

Figure 2.1. *Location of the Operation Porcupine project area showing the main physiographic divisions in Yukon Territory and western District of Mackenzie (after Mathews, 1986; Bostock, 1948).*

by other air photographs and ground pictures, to display the physiography of this spectacular part of the North American Cordillera.

Norris (1985), following Hughes (1972), differentiated and mapped several types of unconsolidated Quaternary deposits, and incorporated them with the bedrock geology maps.

The project area lies entirely within the zone of continuous permafrost and includes the transition from northern alpine to lowland arctic permafrost (Harris et al., 1983a). Much of Mackenzie Shelf was exposed during late Wisconsinan and earlier glaciations, allowing permafrost to develop there (Heginbottom and Tarnocai, 1983).

The Quaternary history of the area, like the array of physiographic divisions and tectonic elements, is complex. In the Cordilleran Region, the Wernecke and southern Ogilvie Mountains underwent repeated montane glaciation, whereas in other areas, such as Old Crow Flats and Old Crow Pediplain, glaciation never occurred. Instead, these areas contain a wide range of Quaternary colluvial glacial-lacustrine, fluvial and lacustrine deposits and periglacial landforms (Hughes et al., 1983, 1989a).

The Interior Plains and Arctic Coastal Plain regions (including Mackenzie Shelf), on the other hand, were covered by the Late Wisconsinan Laurentide Ice Sheet. The maximum extent of glaciation (Fig. 2.2) is readily traced by the presence of discontinuous moraines, ice-marginal channels and erratics of Shield origin (Hughes et al., 1983). The ice flowed into Bonnet Plume Basin impounding a glacial lake to the west and temporarily diverting Peel River northward across a low divide into Eagle River (Fig. 2.3). At about the same time, the Laurentide Ice Sheet blocked the eastward flow of Eagle and Bell rivers across Richardson Mountains at McDougall Pass and ponded a large glacial lake covering what are now Bell, Bluefish and Old Crow basins. This lake discharged westward into Yukon River forming a canyon (the ramparts of Porcupine River) at the Yukon/Alaska border. By the time McDougall Pass became ice free, the canyon was incised below the level of the pass and westward drainage of Porcupine River into the Yukon was permanently established (Hughes et al., 1989b). The low divide at the headwaters of Eagle River was not sufficiently eroded to cause the permanent northward flow of the upper Peel and Ogilvie rivers into Bell Basin.

PHYSIOGRAPHIC DIVISIONS

Only the extreme northwest corner of Mackenzie Mountains lies within the project area. There, uplifted erosional remnants of deformed middle Paleozoic and older rocks lie adjacent to prominent mesas of undeformed Cretaceous Trevor Formation (Fig. 3.7). The physiographic boundary between the mountains and the plains coincides with the interface between the Frontal Belt of the Cordilleran Orogen and the relatively undeformed rocks of the northern Interior Platform.

West-trending Mackenzie Mountains terminate at a major physiographic break with the structurally depressed segment of Richardson Mountains identified as Bonnet Plume Basin (Figs. 2.1, 2.4). It was there, during Late Wisconsinan time, that part of the Laurentide Ice Sheet diverted Peel River northward into Eagle Plain (Harris et al., 1983b).

The structural grain of Richardson Mountains predates the Quaternary and, therefore, passes beneath Bonnet Plume Basin to surface again in Wernecke Mountains. There, in the drainage of Rapitan Creek, occur some of the most spectacular debris-covered glaciers to be seen anywhere (O.L. Hughes, pers. comm., 1991; Fig. 2.5). Steep-walled, V-shaped canyons are choked with large, angular blocks of Quartet Group argillites and quartzites that appear to be moving caterpillar-style down the valleys.

The north-trending Richardson Mountains can be divided into a northern and a southern part based upon their physiographic and structural character. The boundary between the two lies in the structural and topographic depression at the headwaters of Vittrekwa River, where the Dempster Highway crosses the mountains. The southern Richardsons are basically in the form of a breached anticlinorium (Figs. 2.3, 3.9), with sandstone and limestone (Slats Creek and Illtyd formations) in its core and resistant chert and limestone (Road River Formation) forming its rim. Because of the gentle northerly plunge of the anticlinorium, the rim rock wraps around the anticlinorium in classical canoe-shaped fashion. Northern Richardson Mountains, on the other hand, are made up of highly faulted and folded, predominantly clastic rocks so that ridges formed through differential erosion commonly have limited lateral extent (Figs. 2.6, 2.7). As will be seen in Chapter 3, the northern Richardsons are part of the northeast-trending Aklavik Arch Complex. There, one of the best examples of cryoplanation terracing in the northern Cordillera occurs in quartzites of the Jurassic Bug Creek Group (Figs. 2.7, 2.8). Moreover,

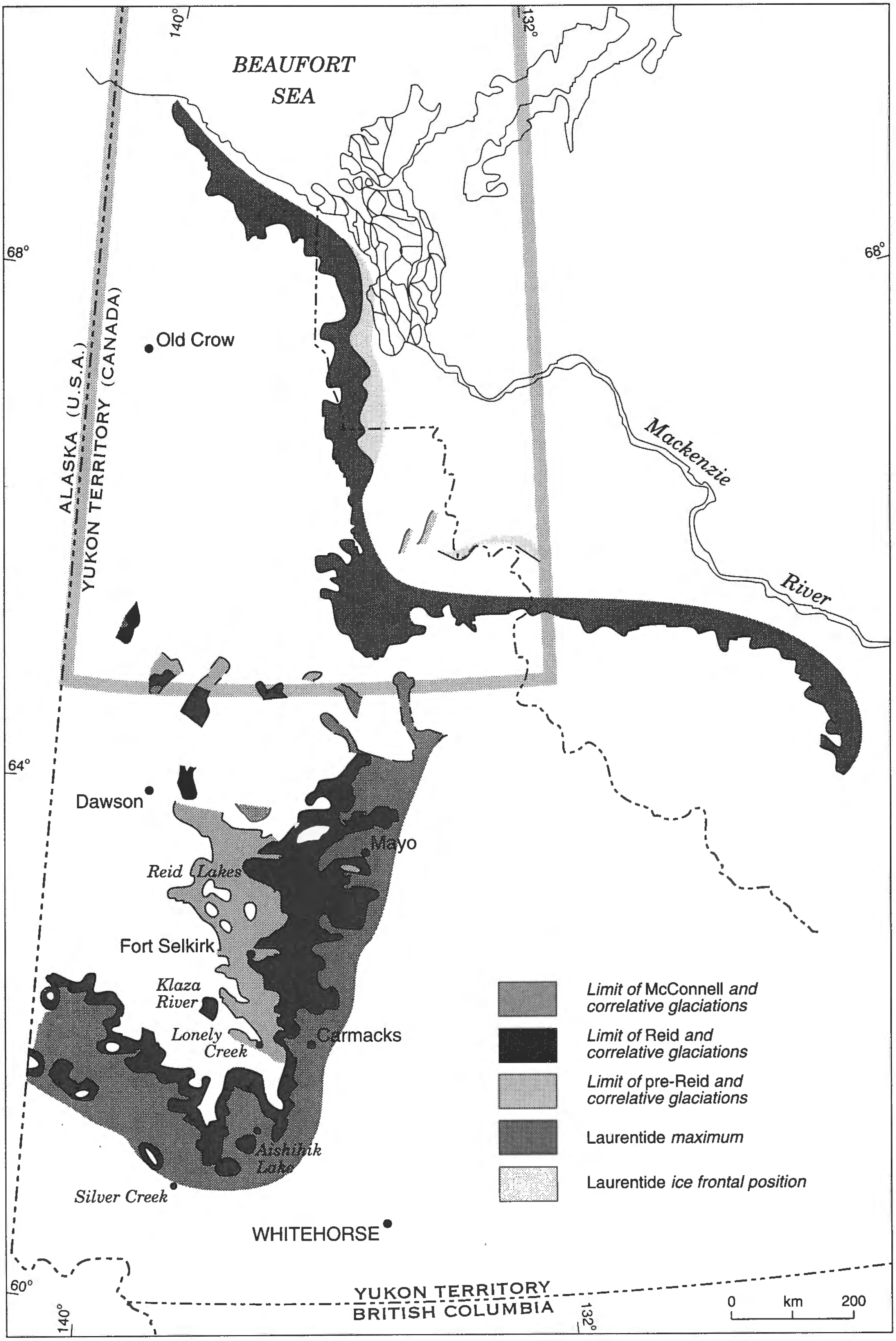
BEAUFORT SEA
140°
132°
68°
68°
64°
60°
140°
132°
ALASKA (U.S.A.)
YUKON TERRITORY (CANADA)
Old Crow
Mackenzie River
Dawson
Mayo
Reid Lakes
Fort Selkirk
Klaza River
Lonely Creek
Carmacks
Aishihik Lake
Silver Creek
WHITEHORSE
YUKON TERRITORY
BRITISH COLUMBIA
0 km 200
Limit of McConnell and correlative glaciations
Limit of Reid and correlative glaciations
Limit of pre-Reid and correlative glaciations
Laurentide maximum
Laurentide ice frontal position

Figure 2.3. *Richardson Anticlinorium outlined by relatively resistant lower Paleozoic Road River Formation* (ЄDR), *in the vicinity of Canyon Creek* (CC). *In the late Pleistocene, Peel River was diverted northward through the abandoned channel occupied by Davis* (D) *and Moose* (M) *lakes (left middleground) in the headwaters of Eagle River. View is to the north. NAPL photo T4–84R.*

Figure 2.4. *Northwesternmost Mackenzie Mountains (Knorr Range) and southern Bonnet Plume Basin. Bonnet Plume River* (BPR) *flows from Wernecke Mountains (upper left). View is to the south. NAPL photo T4–96R.*

Figure 2.5. *Debris-covered glacier on Proterozoic Quartet Group at the headwaters of Rapitan Creek, northern Wernecke Mountains. View is to the south. GSC photo 3566-8.*

Figure 2.6. Ridge-forming clastic rocks of the northern Richardson Mountains, with a resistant core of white weathering limestone comprising White Mountains. View is to the south. NAPL photo T5–22L.

spectacular pediplains occur on both flanks of the Richardsons (Figs. 2.3, 3.9) as well as in the core of the anticline (Fig. 2.9). At least five generations of pediplains can be identified in the core of the range, suggesting aperiodic, differential uplift of the anticlinorium in the late Tertiary and Quaternary.

One of the great deflections in mountain trends in the Frontal Belt of the Cordilleran Orogen occurs where the west- and north-trending Ogilvie Mountains meet at the headwaters of Ogilvie River. Both structures and facies trends in many formations are continuous around the deflection, suggesting that they are the underlying control of the curvilinear structural and physiographic grain characterizing Ogilvie Mountains, and that they are part and parcel of one physiographic division rather than two.

Eagle Lowland is more or less equidimensional in plan view. It is surrounded by mountains: the Ogilvies on the west and south, the Richardsons on the east and north, and Dave Lord Range on the north. Although not a lowland in the sense of Yukon Coastal Plain, it is physiographically subdued because of its cover of relatively less resistant, gently folded, unglaciated, Mesozoic clastic rocks.

Unglaciated northwestern Yukon Territory includes Keele, Dave Lord and Old Crow ranges. Keele and Dave Lord ranges are fault-bounded, uplifted blocks separating Bell and Bluefish basins[1] on Old Crow Pediplain. Old Crow Range is a structurally high, erosionally resistant massif separating western Old Crow Flats from Bluefish Basin. Within the flats is a myriad of lakes, many rectangular in shape (Fig. 2.10), with their long axes trending northwest in the direction of the prevailing winds.

Thick, unconsolidated sediments are extensive on Old Crow Flats and on Old Crow Pediplain. According to Hughes et al. (1989b) they are mainly of fluvial, lacustrine and glacial lacustrine origin and are by far the most important Quaternary deposits in the project area. They contain not only the stratigraphic record of the Pleistocene for the region, but also bones thought to be human-modified (Morlan, 1980). Abandoned beaches and spits on the pediplain slopes bordering Old Crow Flats mark former levels of a large glacial lake that occupied Bell, Bluefish and Old Crow basins when the Laurentide Ice Sheet blocked eastward drainage.

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[1] Bell and Bluefish basins are not identified on Fig. 2.1. Refer to Hughes, 1972.

Figure 2.7. *Northeastern Richardson Mountains and part of Aklavik Arch Complex. Rat River* (RR), *Scho Uplift* (SU) *and McDougall Pass* (MP) *are in the middle background. Note cryoplanation terraces with risers outlined by snow (lower centre). View is to the south. NAPL photo T3–19L. See also Fig. 2.8 for the same feature.*

Figure 2.8. Cryoplanation terraces in Jurassic Bug Creek quartzites, northern Richardson Mountains. View is to the southwest. GSC photo 1122–4. See also Fig. 2.7.

Overlooking the flats from the west, on the crest of Old Crow Range, are clusters of granite tors (see cover photograph), majestically resisting agents of weathering and erosion.

Old Crow Pediplain is a vast amalgamation of Late Tertiary and Quaternary erosion surfaces inclined gently toward the lowlands of Bell, Bluefish and Old Crow basins, and extending from Keele and Dave Lord ranges north to British and Barn mountains.

British and Barn Mountains are early to mid-Tertiary, unglaciated, uplifted blocks separating Old Crow Pediplain from Yukon Coastal Lowland. British Mountains (Fig. 3.29) are separated from the Barn Mountains (Fig. 3.30) by a topographic and structural depression occupied by Babbage River. Like Firth River to the west, the Babbage flows north through the mountains so that the divide between the Porcupine River drainage and the Yukon north slope drainage is well south of the crest of the ranges. Clearly, downcutting of the Firth, Babbage and their tributaries must be keeping pace with differential uplift of the ranges.

West of Mackenzie Delta, Yukon Coastal Lowland (Fig. 2.11) forms the interface between the Arctic Ranges and Mackenzie Shelf. East of the Delta, a small part of Anderson Plain occurs within the project area. Both the Lowland and the Plain were covered occasionally by the Laurentide Ice Sheet (Fig. 2.2); its glacial deposits were plastered on a grand pediplain. Today, this pediplain extends from Mackenzie Delta across Yukon Territory into Alaska and masks the underlying bedrock structure.

Figure 2.9. *Dissected pediments on highly deformed siltstones and quartzites of the Upper Devonian Imperial Formation in the core of Richardson Mountains. View is to the northeast from Dempster Highway. GSC photo 2048–187.*

Figure 2.10. *Western Old Crow Flats at the headwaters of Old Crow River, showing characteristic rectangular lakes elongated northwest, parallel to the prevailing wind directions. View is north–northwest. NAPL photo T14L–144.*

Figure 2.11. Yukon Coastal Lowland showing hummocky moraine deposited by the Laurentide Ice Sheet adjacent to the Beaufort Sea shoreline south of Kay Point. Herschel Island is visible in the upper left background. View is to the north. NAPL photo T29R–35.

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CHAPTER 3

GEOLOGICAL SETTING

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with contributions from P.W. Basham, D.A. Forsyth, and R.J. Wetmiller

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Abstract

The project area embraces two genetically and structurally distinct regimes: the relatively undeformed Interior Platform, and the deformed Frontal Belt of the Cordilleran Orogenic System. The supracrustal wedge comprising them tapers eastward and northward, and rests with profound unconformity on continental crust, except possibly beneath southern Beaufort Sea where it is interpreted to rest upon transitional or oceanic crust.

The wedge is made up of platformal, miogeoclinal and eugeoclinal sedimentary, volcanic and intrusive rocks spanning about 1700 Ma. Regional unconformities, some spectacularly angular, divide it into seven tectonostratigraphic sequences, the very presence or absence of which highlights source areas and depositional sites in any time interval represented by a given sequence.

Twenty-one tectonic elements or building blocks are defined in the project area, twenty within the orogen and one in the Interior Platform. They are recognized by their structural attributes and by the sequences they contain. Individually, the elements provide basic information on the local evolutionary history of the project area. Collectively, they reveal the grand design of one of the most mobile segments of the Frontal Belt in Canada. This is especially important because the project area embraces the geological link among the Cordilleran, Innuitian and Alaskan orogens and, in turn, holds a key to understanding the tectonic evolution of the Arctic Ocean basin.

Résumé

La région à l'étude englobe deux régimes génétiquement et structuralement distincts : la Plate-forme de l'Intérieur relativement non déformée et le domaine frontal déformé du système orogénique de la Cordillère. Le biseau supracrustal qui les comprend s'amincit vers l'est et le nord pour ensuite reposer en discordance profonde sur la croûte continentale, sauf peut-être sous le sud de la mer de Beaufort où il reposerait sur la croûte transitionnelle ou océanique.

Le biseau est composé de roches sédimentaires, volcaniques et intrusives de plate-forme, de miogéosynclinal et d'eugéosynclinal dont l'intervalle d'âge couvre environ 1 700 Ma. Les discordances régionales, certaines exceptionnellement angulaires, le divisent en sept séquences tectonostratigraphiques, dont la présence ou l'absence met en évidence les zones d'origine et les sites de sédimentation dans tout intervalle chronologique représenté par une séquence donnée.

On a défini 21 éléments tectoniques ou blocs de construction dans la région à l'étude, dont 20 dans l'orogène et un dans le Plate-forme de l'Intérieur. On les distingue par leurs attributs structuraux et par les séquences qu'ils contiennent. Individuellement, les éléments fournissent des informations de base sur l'évolution locale de la région à l'étude. Collectivement, ils révèlent la disposition globale de l'un des segments les plus mobiles du domaine frontal du Canada. Ce fait est particulièrement important étant donné que la région à l'étude porte sur le lien géologique qui unit l'orogène de la Cordillère, l'orogène innuitien et l'orogène alaskien et, par le fait même, détient la clé permettant de comprendre l'évolution tectonique du bassin de l'océan Arctique.

INTRODUCTION

The project area embraces part of the northern Canadian Cordillera and adjacent Interior Platform extending from the lower Mackenzie River in the east to the international boundary with Alaska in the west, and from the crest of Ogilvie Mountains in the south to the southern edge of Canada Basin (Fig. 3.1; Norris, 1985a[1]). About two-thirds of the area lies in Yukon Territory and one third in western District of Mackenzie.

The area includes two genetically and structurally distinct regimes: 1) the Cordilleran Orogenic System; and 2) the northern Interior Platform. The orogenic system occurs both onshore and offshore whereas the platform is almost entirely onshore.

The Cordilleran Orogenic System in northern Canada has been characterized by its marked crustal instability since the beginning of the Proterozoic. The cumulative effects of successive orogenies has resulted in a structural style in stark contrast to that of any other segment of the Foreland Thrust and Fold Belt in Canada. Onshore, angular unconformities, diverse structural trends, fold bundles, and extension, contraction and transcurrent faults abound. Offshore, Upper Cretaceous and Cenozoic sediments blanket the northward continuation of the orogen and, correspondingly, the true nature of the structural and stratigraphic links between it and the Innuitian Orogen of the Arctic Archipelago. The northwestward continuity of the orogenic system through northern Yukon Territory into Alaska, on the other hand, is abundantly clear.

The Cordilleran Orogenic System is made up of the Pacific Orogen on the west and the Columbian Orogen on the east (Wheeler and Gabrielse, 1972); the dividing line between the two occurs within the Intermontane Belt. The Columbian Orogen, therefore, is made up of part of the Intermontane Belt, the entire Omineca Crystalline Belt, and the outer or Frontal Belt (new term; previously known as the Foreland Thrust and Fold Belt). As will be explained later in this chapter, in northern Yukon Territory the Columbian Orogen bifurcates into the Alaskan and Innuitian orogens. The Cordilleran Orogenic System, therefore, embraces parts of the Cordilleran, Alaskan and Innuitian orogens.

The northern Interior Platform, on the other hand, by its very nature, is characterized by relative crustal stability and structural simplicity. It comprises a gently westward-dipping homoclinal sedimentary succession of Phanerozoic rocks resting unconformably upon Proterozoic sediments and volcanics deformed into intracratonic uplifts, warps and sags (Cook and MacLean, 1992). The whole rests with pronounced unconformity on the westward continuation of the Canadian Shield. Major epeirogenic hiati separate the depositionally thinner, layer-parallel stratigraphic packages and, except in proximity to the orogen, the packages are relatively unfaulted and only gently folded.

THE SUPRACRUSTAL WEDGE

Regionally, within the northern Interior Platform, the sedimentary succession comprises an eastward-tapering, supracrustal wedge. It ranges in thickness from 0 km at the edge of the Canadian Shield, to an estimated 7 km along the interface between the platform and the orogen adjacent to southern Richardson Mountains (Norris, 1985b), to about 16 km near the edge of the platform northeast of the Tuktoyaktuk Peninsula (Dietrich et al., 1989). Within the orogen, estimates of the thickness of the wedge range from 20 km on land (Norris, 1985b) to about 14 km close to the outer edge of the continental shelf (Dietrich et al., 1989).

The supracrustal wedge is made up of two genetically and compositionally distinct stratigraphic assemblages analogous to those observed in the Frontal Belt of southern Canada (Norris, 1985b). The lower assemblage, or infrawedge, embraces Proterozoic (and older?) to Lower Cretaceous platformal, miogeoclinal and eugeoclinal sedimentary, basic volcanic and acid intrusive rocks, spanning more than 1500 Ma (1700 Ma–130 Ma). If the crystalline basement beneath it includes those rocks remobilized and recrystallized by the Hudsonian Orogeny, its age would be in the order of 1735 Ma.

The overlying suprawedge in northwestern Canada consists of the Lower Cretaceous to Paleogene exogeoclinal assemblage, spanning approximately 80 Ma (about 130–50 Ma). It is the synorogenic and postorogenic suite of terrigenous clastics, shed primarily eastward and northward from regions deformed and uplifted in the Columbian and Laramide orogenies. Collectively, the two assemblages form the

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[1] Note: GSC Map 1581A is the standard reference to the regional geology of the project area for this volume. It was compiled from the 1:250 000 scale A-Series reconnaissance geological maps with some updating. Where differences are encountered between the reconnaissance maps and the compilation, the latter (1581A) shall prevail.

stratigraphic link among the northern Rocky Mountains of British Columbia, the Alaskan Orogen north of the Kobuk Fault, and the Innuitian Orogen.

TECTONOSTRATIGRAPHIC SEQUENCES

Of the unconformities punctuating the stratigraphic succession of the supracrustal wedge, many are regional whereas others are local. They play an important role in the division of the wedge into seven, discrete tectonostratigraphic sequences (Table 3.1) that are continuous throughout large areas of the northern mainland, as well as the southern Arctic Archipelago. They include, with modification (Norris and Yorath, 1981), two of the original sequences of Lerand (1973; Franklinian, Ellesmerian), the Inuvikian (Norris and Yorath, 1981) and the Werneckian and Rapitanian (Norris, 1983a) to identify the stratigraphically lowest observed sequences. Additionally, I subdivided the highest (Brookian; Lerand, 1973) into an older Columbian and a younger Laramidian sequence. The oldest five make up the infrawedge, and the youngest two, the suprawedge.

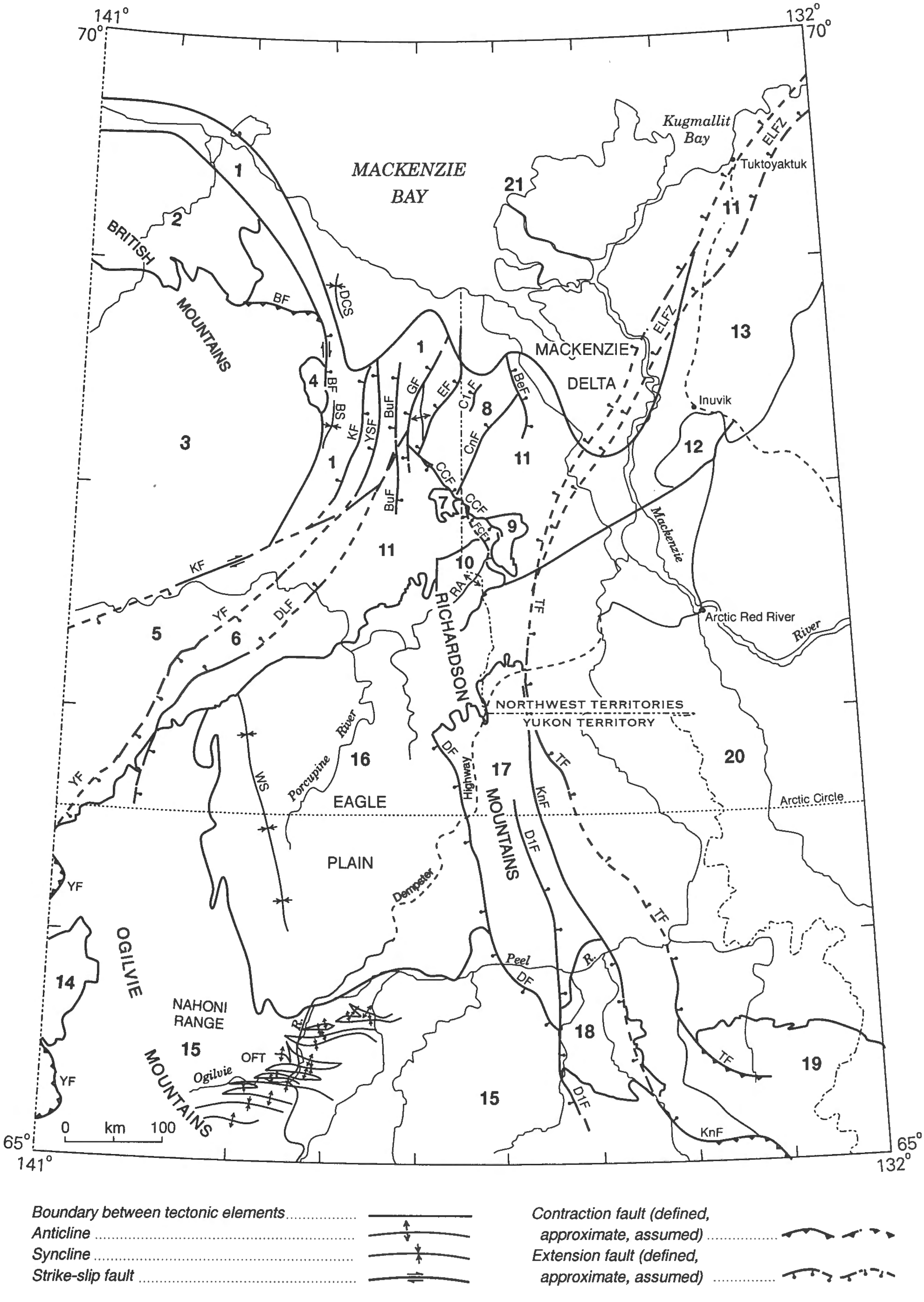
Werneckian (W)

The Werneckian, or oldest sequence, embraces the slaty argillites, quartzites, dolomites and intrusive breccias of the Wernecke Supergroup, deformed in the Racklan Orogeny (Young et al., 1979). It is separated from the overlying Inuvikian Sequence by a spectacularly angular unconformity (Fig. .2). Moreover, the dominance of mud rocks suggests, for the most part, a deep water depositional environment. Werneckian rocks appear to underlie much if not all of the project area (Chapter 4). Radiometric ages from the breccias indicate that Werneckian strata may be as old as Aphebian (Archer et al., 1977).

Table 3.1

Tectonostratigraphic Sequences

Sequence	Age	Facies	Symbol
Laramidian	Late Cretaceous–Middle Eocene (70–45 Ma)	Ss, Sh	L
Laramide Orogeny (70–45 Ma)			
Brookian (undivided)	Early Cretaceous–Middle Eocene (130–45 Ma)	undifferentiated Columbian and Laramidian	B
Columbian	Early Cretaceous–Late Cretaceous (130–70 Ma)	Ss, Sh	C
Columbian Orogeny (130–90 Ma)			
Ellesmerian	Early Carboniferous–Early Cretaceous (360–130 Ma)	Ls, Dol, Sh, Ss	E
Ellesmerian Orogeny (375–355 Ma)			
Franklinian	Early Cambrian–Early Carboniferous (570–360 Ma)	Ls, Dol, Ss	F
unnamed event (600–560 Ma)			
Rapitanian	Hadrynian (800–570 Ma)	Sh, Ss, Dol, Cgl	R
Hayhook Orogeny (900–800 Ma)			
Inuvikian	Helikian (1200–800 Ma)	Ls, Dol, Ss	I
Racklan Orogeny (1300–1200 Ma)			
Werneckian	Aphebian(?)–Helikian (1700–1200 Ma)	Sh, Dol, Brx	W
Hudsonian Orogeny (1700 Ma +/-)			


141°
70°
132°
70°
MACKENZIE BAY
Kugmallit Bay
Tuktoyaktuk
BRITISH MOUNTAINS
MACKENZIE DELTA
Inuvik
Mackenzie
Arctic Red River
River
RICHARDSON MOUNTAINS
NORTHWEST TERRITORIES
YUKON TERRITORY
Porcupine River
EAGLE PLAIN
Dempster Highway
Arctic Circle
Peel R.
OGILVIE MOUNTAINS
NAHONI RANGE
Ogilvie R.
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
BF
DCS
BS
KF
YSF
BuF
GF
EF
CLF
BeF
CnF
CCF
LFCF
RAA
ELFZ
TF
YF
DLF
WS
DF
KnF
DIF
OFT
0 km 100
65°
141°
65°
132°
Boundary between tectonic elements
Anticline
Syncline
Strike-slip fault
Contraction fault (defined, approximate, assumed)
Extension fault (defined, approximate, assumed)

Tectonic elements (in order of presentation)

20	Interior Platform
19	Mackenzie Foldbelt
17	Richardson Anticlinorium
18	Bonnet Plume Basin
15	Taiga-Nahoni Foldbelt
14	Kandik Basin
16	Eagle Foldbelt
	Aklavik Arch Complex (5-13)
5	Keele Block
6	Dave Lord Uplift
11	Canoe Depression
8	Cache Creek Uplift
7	White Uplift
10	Rat Uplift
9	Scho Uplift
13	Eskimo Lakes Block
12	Campbell Uplift
2	Romanzof Uplift
3	Old Crow-Babbage Depression
4	Barn Uplift
21	Beaufort-Mackenzie Basin
1	Rapid Depression

Faults and folds:

BF	Barn Fault
BeF	Beaver Fault
BS	Blow Syncline
BuF	Buckland Fault
CCF	Cache Creek Fault
CnF	Canoe Fault
ClF	Castle Fault
DLF	Dave Lord Fault
DF	Deception Fault
DCS	Deep Creek Syncline
DlF	Deslauriers Fault
EF	Eagle Fault
ELFZ	Eagle Lake Fault Zone
FCF	Fish Creek Fault
GA	Gilbert Anticline
GF	Gilbert Fault
KF	Kaltag Fault
KnF	Knorr Fault
OFT	Ogilvie Fold Train
RA	Rat Anticline
TF	Trevor Fault
WS	Whitestone Syncline
YT	Yukon Fault
YSF	Yukon (Skull) Fault

Figure 3.1. *Location map for the principal tectonic elements and structures referred to in Chapter 3. Tectonic elements are numbered 1 through 21. Faults and folds, listed alphabetically, are identified by abbreviations.*

Inuvikian (I)

The Inuvikian Sequence includes shelf carbonates and clastics of the Mackenzie Mountain and Pinguicula supergroups. The sequence is widespread in the Mackenzie Mountains and in the subsurface of the northern Interior Platform. It comes to the surface in the core of Campbell Uplift (Fig. 3.3) where a virtual geomagnetic dipole would suggest a paleomagnetic age of about 1.1 Ga (Norris and Black, 1964).

Rapitanian (R)

The Rapitanian Sequence embraces the stratigraphic interval lying disconformably (Hayhook Orogeny; Young et al., 1979) upon the Inuvikian and overlain unconformably by the Franklinian. It includes the glaciogenic Rapitan Formation of northwestern Mackenzie Mountains (Fig. 3.4) and the coeval upper Tindir Group of western Ogilvie Mountains, along the boundary with Alaska. The Rapitanian Sequence is homotaxial with the Windermere Supergroup of southeastern British Columbia.

Franklinian (F)

The Franklinian Sequence is the interregional succession from the base of the Cambrian System to the top of the Devonian (Norris and Yorath, 1981). It includes a basal, shallow-water clastic unit, overlain by a widespread blanket of reefoid platform carbonates (Fig. 3.5) and clastics. It rests unconformably upon the Werneckian, Inuvikian, or Rapitanian sequences, depending upon its position within the orogen or platform.

Ellesmerian (E)

The Ellesmerian Sequence includes the carbonate and clastic succession extending from the Lower Carboniferous to the mid-Lower Cretaceous. It is bounded below and above by interregional unconformities, the lower one embracing the latest Devonian and earliest Carboniferous Ellesmerian Orogeny (Fig. 3.6), and the upper one, the Columbian Orogeny.

Columbian (C)

The Columbian Sequence in northwestern Canada embraces the fine to coarse clastic formations from the mid-Lower Cretaceous to the lower Upper Cretaceous. It includes, therefore, the entire sedimentary record of the fundamental redistribution of source areas and depositional basins concurrent with the onset of the Columbian Orogeny. Both its base and its top are unconformable. It is widespread, thickest in the western half of the area, and preserved as a remnant of the migrating Columbian Foredeep (Fig. 3.7) on the Interior Platform. In those areas where the Columbian and Laramidian are undifferentiated, they are referred to as the Brookian Sequence.

Laramidian (L)

The Laramidian fine to coarse grained clastics in northwestern Canada range in age from latest Late Cretaceous to early Tertiary (mid-Eocene), and perhaps to late Miocene (J. Dixon, pers. comm., 1993) if the structures in the Beaufort–Mackenzie Basin are primarily compressional. These sediments are the record of the latest compressional event to affect the Cordilleran Orogenic System. In the project area their thin, southern feather edge is preserved on the Yukon Coastal Lowland in the vicinity of the mouths of Big Fish (Fig. 3.8) and Babbage rivers, and in Caribou Hills east of Mackenzie Delta. Seaward on the continental shelf they are up to 10 km thick (Dietrich et al., 1989).

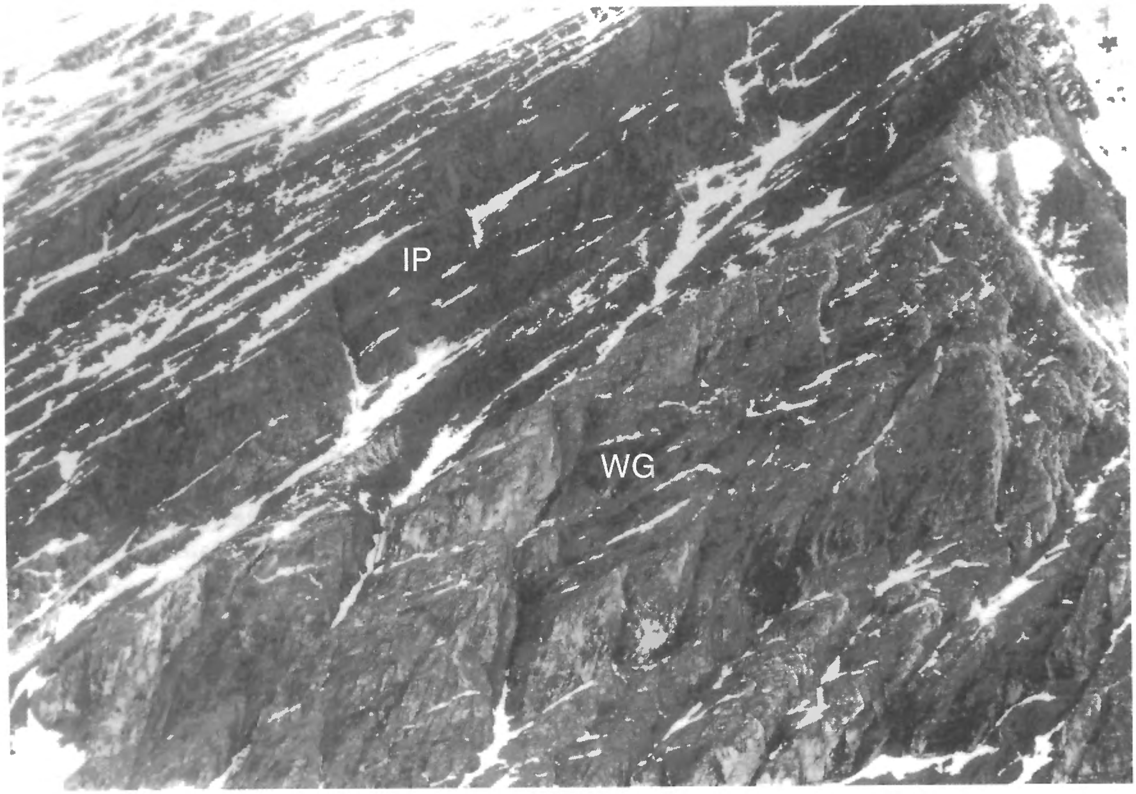


Figure 3.2. *Aerial view of the angular unconformity between pale orange weathering dolomite of Werneckian Gillespie Lake Group* (WG) *and dark grey clastics and carbonates of Inuvikian Pinguicula Group* (IP), *at the headwaters of Rapitan Creek, Snake River map area, Yukon Territory. ISPG photo 1860–20, looking east.*

TECTONIC ELEMENTS

Twenty-one tectonic elements are defined in the project area. Twenty of them make up the Frontal Belt of the Cordilleran Orogen and one of them, the contiguous Interior Platform (Norris, 1983a). Collectively, the former contains the record of structural and stratigraphic complexities of one of the most mobile segments of the Frontal Belt in Canada. The latter is representative of the stable craton extending, in Canada, from the Aklavik Arch Complex to the 49th parallel. Criteria used to distinguish and define them include: the continuity and/or homogeneity of the deformation; the trend and arrangement of axes in en echelon fold bundles; major extension, contraction or strike-slip faults occurring either singly or in arrays; structural depressions or uplifts; and regional as well as parochial unconformities. The elements are recognized from their cumulative structural style, including their relatively positive or negative stance in response to the youngest or Laramide Orogeny that affected the region. From the unconformities within them, as well as from the depositional environments interpreted from their associated sedimentary rocks, it is apparent that some elements were more mobile than others. They were intermittently extended, compressed, displaced laterally, and tectonically uplifted and depressed throughout their evolutionary history. Others suffered only occasional epeirogenic uplift and depression. The elements and subelements are numbered consistently throughout this volume, most of them following the Geotectonic Correlation Chart (Norris, 1983a) for the Operation Porcupine project area. In addition, the Beaufort-Mackenzie Basin (21)[1] is included.

Northern Interior Platform (20)

Northern Interior Platform is made up of the relatively undeformed supracrustal wedge that interfaces with the Frontal Belt. It covers about one third of the project

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[1] Numbers in brackets refer to the order of elements in Fig. 3.1

Figure 3.3. *Pale orange and red dolostone of unnamed Inuvikian formation dipping gently north off the flank of Campbell Uplift at GSC Section 107B3 (see Appendix 2 for explanation of GSC section), in a quarry adjacent to Inuvik airport, Aklavik map area, Northwest Territories. Like the lower Paleozoic carbonate rocks overlying them, these strata contain fissures filled with bentonite-rich siltstone that, elsewhere on the uplift, contain Middle to Late Albian foraminifera (Chapter 13). ISPG photo 2049–33.*

area. The formations comprising it are layer-parallel and flat-lying to very gently dipping to the west. It is believed that Werneckian and Inuvikian sedimentary and igneous rocks underlie the entire area (Chapter 4, Table 4.1) and are overlain unconformably by Franklinian carbonates and clastics. A thin wedge of lower Ellesmerian Sequence is preserved around Fort McPherson, beneath the regional unconformity at the base of the Columbian Exogeocline. No Laramidian rocks are known from the Interior Platform in the project area.

Mackenzie Foldbelt (19)

Mackenzie Foldbelt embraces that part of the Columbian Orogen between the western margin of the northern Interior Platform and Selwyn Foldbelt (Fig. 3.1). The arcuate length of the belt is about 950 km. Only the northwest extremity of the belt occurs within the project area. Fold bundles with associated strike-slip or oblique-slip faults dominate the structural style. They swing in a great curve (Mackenzie Deflection) to outline the structural front

Figure 3.4. Rapitan diamictite exposed on Iron Creek, a tributary from the east of Snake River, Snake River map area, Yukon Territory. Clasts of unsorted quartzite, dolomite (some with algal structures) and acid and basic igneous rocks range in maximum dimension up to 50 cm. ISPG photo 662–45.

of the Columbian Orogen as it changes trend from a northerly strike in the vicinity of the 60th parallel to a westerly strike in the vicinity of Arctic Red River.

Characteristic of these bundles is the arrangement of folds or fold pairs in en echelon arrays so that the folds systematically overlap one another to the right or left, depending upon their position on the deflection (Norris, 1972a, 1985b). Ideally, the traces of axial surfaces of the folds are curvilinear to rectilinear, whereas in actuality, many are highly sinuous, suggesting refolding of the bundles. Moreover, individual folds in a given bundle are not exclusively right- or left-hand en echelon, although a dominant configuration commonly occurs.

On the west-trending leg of Mackenzie Deflection, which reaches into the extreme southwest corner of the project area, the folds are characteristically arranged left-hand en echelon and strike northwest at an acute angle to the trend of the mountain front. Mackenzie Foldbelt terminates at the Richardson Anticlinorium.

Richardson Anticlinorium (17)

Richardson Anticlinorium is the broad, gently north-plunging anticlinal structure between the autochthon of the northern Interior Platform on the east and Eagle Foldbelt on the west (Fig. 3.1). It is bounded for much of its length on the east by Trevor Fault (Fig. 3.9, 3.10) and on the west by Deception Fault. The anticlinorium coincides in position with the early and middle Paleozoic Richardson Trough (Lenz, 1972). Deep-water, graptolitic shale and argillaceous limestone, with resistant interbeds of limestone breccia composed of debris shed from coeval carbonate shelves flanking it, comprise the dominant lithologies of the Road River Formation on the flanks of the anticlinorium. In its core, moreover, Lower Cambrian limestone of the Illtyd Formation overlies phyllitic argillite and quartzite of the Wernecke Supergroup with angular unconformity (Fig. 3.11). The omission of more than 10 km of younger Proterozoic rocks (more than one half of the estimated total thickness of the supracrustal wedge in this area) at this unconformity is strongly suggestive of major block faulting and potential involvement of the Hudsonian(?) crystalline basement in the faulting prior to the Early Cambrian (Norris, 1985b).

The anticlinorium is laced with north-trending, curviplanar, near-vertical faults comprising the Richardson Fault Array (Fig. 3.12), traceable for 600 km from Tuktoyaktuk Peninsula to the Mackenzie Mountains. Northeastward, the array appears to continue across the continental shelf to connect with the Cape Kellett Fault Zone (Norris and Yorath, 1981), west of Banks Island. Southward, the array veers to the southeast and changes style from a zone of nearly vertical strike-slip faults to one of steeply-dipping, high-angle oblique-slip faults (Fig. 3.13). Its total length, including these extrapolations, therefore, may be on the order of 1000 km. The great length of the array, the stratigraphic contrasts from one side of the array to the other and from one fault block to another, and the reciprocation of uplifted and downdropped blocks across as well as along the fault zone collectively identify Richardson Fault Array as a fundamental structure of the lithosphere.

Various strands of the array have known right-lateral separations up to 40 km and illustrate the cumulative effects of dextral shear (the older the rocks involved in the faulting, the larger the horizontal separation). The most dramatic evidence for these displacements may be seen on the south flank of Bonnet Plume Basin, in the vicinity of Margaret Lake. Immediately west of Knorr Fault, the Proterozoic section is much abbreviated. Diamictite of the Rapitan Formation (Fig. 3.4) rests unconformably on Wernecke Supergroup, the oldest rocks known in the Proterozoic succession. Large parts of the Inuvikian and Rapitanian sequences are absent at the unconformities marking the upper and lower boundaries of the diamictite. East of Knorr Fault, in Knorr Range, mudstone correlated with basinal parts of the Rapitan are overlain by 2000 m of younger Rapitanian rocks and underlain by more than 5000 m of Inuvikian strata. The region west of Knorr fault must have been relatively uplifted during deposition of the upper Inuvikian and the upper Rapitanian sequences to account for these stratigraphic omissions. Moreover, the structural position of the diamictite opposite Knorr Range would suggest that the diamictite unit was displaced right-laterally about 40 km northwest of its counterpart across the fault, at the headwaters of Snake River (Norris and Hopkins, 1977).

Less right-lateral strike-slip displacement is suggested across Deslauriers Fault in Phanerozoic rocks on the west flank of Bonnet Plume Basin (Norris, 1982a). There, the continuation of the southeast-trending panel of lower and middle Paleozoic rocks comprising Mount Deception is found immediately east of the fault, approximately 20 km to the south in Illtyd Range (Fig. 3.13).

Finally, small-scale displacement is observed in Upper Devonian and younger rocks where they wrap around the nose of north-plunging Richardson Anticlinorium (Norris, 1981a). There, the Upper Devonian Canol Formation is offset right-hand about 8 km on one strand of Richardson Fault Array.

Insofar as Jura-Cretaceous and younger formations lack horizontal separations across the array, it would

Figure 3.5. *Resistant lower Paleozoic limestone and argillaceous limestone of map unit ꞒDb on Royal Mountain, adjacent to GSC Section 106E12 and the shale-out to Road River Formation, Wind River map area, Yukon Territory (see Norris, 1982a). GSC photo 1584–71, looking northwest.*

Figure 3.6. *Rapid Fault Array in Rapid Depression at the headwaters of Blow River, Blow River and Davidson Mountains map area, Yukon Territory. Conglomerate and sandstone of Lower Carboniferous Kekiktuk Formation* (CKk) *lie unconformably upon slaty argillite* (OSh), *presumed to be coeval with the lower and middle Paleozoic Road River Formation. Downthrown walls are identified by black dashes.* KF *is Kaltag Fault;* BL *is Bonnet Lake. NAPL oblique photo T13R–114, looking south.*

appear that strike-slip displacement ceased largely, if not completely, by the close of the Paleozoic Era.

The Richardson Fault Array was the underlying structural control of both Richardson Trough and Richardson Anticlinorium. Evidence for the sense of displacement in the array indicates that, from the late Proterozoic through the Devonian, the faults were primarily dextral strike-slip (Norris and Yorath, 1981, p. 82) and vertical separations in concert with dextral

Figure 3.7. Sandstone mesas of mid-Cretaceous Trevor Formation (KTR) *comprising erosional remnants of the Columbian Foredeep on the north flank of Mackenzie Mountains* (MM) *in Snake River map area, northern Yukon Territory immediately west of the boundary with Northwest Territories. The mountain front is the interface between the Frontal Belt of the Columbian Orogen and northern Interior Platform. NAPL oblique photo T5–185R, looking south–southeast.*

shear controlled water depth within the trough. Reactivation of the faults in the Late Cretaceous and continuing intermittently to the mid-Tertiary, on the other hand, was predominantly dip-slip and caused the inversion of the trough into the anticlinorium.

Bonnet Plume Basin (18)

Bonnet Plume Basin is a composite physiographic and structural depression of restricted areal extent close to the eastern margin of the Frontal Belt of the

Figure 3.8. Mudstone and sandstone of Upper Cretaceous Tent Island (KTI) *and Lower Tertiary Moose Channel* (TMC) *formations at GSC Section 117A39 on the northwest flank of Cache Creek Uplift in vicinity of Big Fish River* (BFR), *Blow River and Davidson Mountains map area, Yukon Territory. Northwest Mackenzie Delta and Mackenzie Bay* (MB) *in background. NAPL oblique photo T6–10R, looking north.*

Columbian Orogen, near the southern limit of Richardson Anticlinorium. It rests asymmetrically on the west flank of the anticlinorium (Norris and Hopkins, 1977). The youngest rocks within it are sandstone, shale, conglomerate and coal of the Late Cretaceous and early Tertiary Bonnet Plume Formation.

Prior to the development of Bonnet Plume Basin, Richardson Trough underwent differential compression and uplift that would transform it into an anticlinorium by the Late Cretaceous. The angular unconformity beneath Bonnet Plume Formation near the mouth of Wind River (Fig. 3.14) indicates that the lower and middle Paleozoic Road River Formation

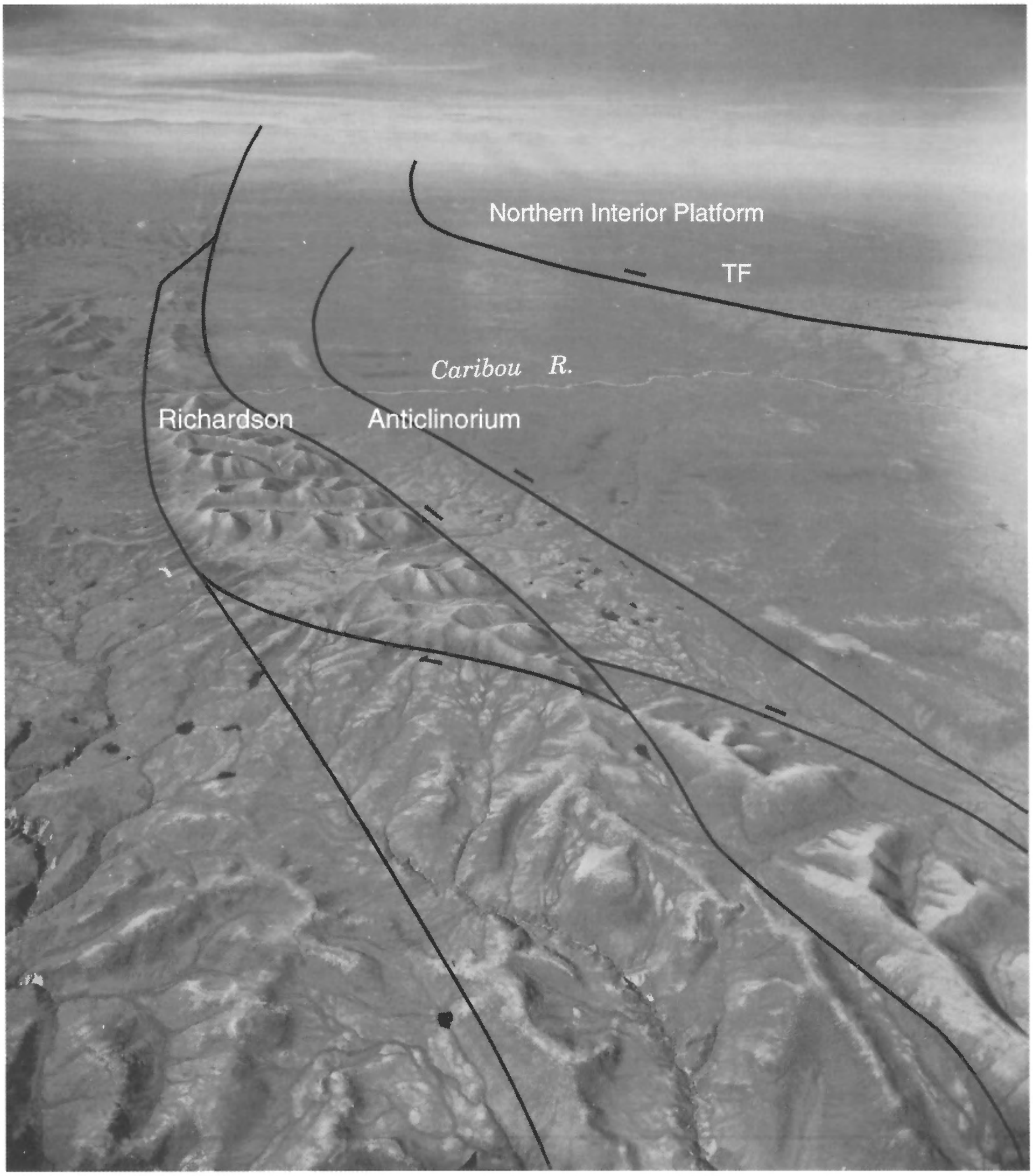

Figure 3.9. *Richardson Anticlinorium and some strands of Richardson Fault Array in southern Richardson Mountains, Trail River map area, Yukon Territory. Trevor Fault* (TF) *defines the interface between the Frontal Belt and the northern Interior Platform. Downthrown walls are identified by black dashes. NAPL oblique photo T4–72R, looking north.*

must have been deformed, uplifted and bevelled prior to development of the basin. Uplift was greatest in the south and resulted in the stripping of Road River and underlying Cambrian formations (Chapter 5) differentially on the north flank of Wernecke Mountains (Norris, 1982a). There, lowermost Upper Cretaceous conglomerate of the lower Bonnet Plume Formation rests on Lower Cambrian Slats Creek and Illtyd formations on some fault blocks and on Werneckian Quartet Group on others.

Bonnet Plume Basin was formed by down-dropping of components of Richardson Fault Array beginning in the early Late Cretaceous, possibly concurrently with

Figure 3.10. *Stable shelf carbonates* (SDu) *juxtaposed with coeval shale (Road River Formation,* ЄDR) *across Trevor Fault* (TF) *at the headwaters of Noisy Creek* (NC), *Wind River map area, Yukon Territory. White bars indicate downthrown walls. NAPL oblique photo T4–100R, looking south.*

continued uplift of Richardson Anticlinorium north of the basin. Local reversal in the sense of relative displacement from the Late Cretaceous to the early Tertiary caused the development of the successor basin in which the Bonnet Plume Formation was deposited.

The two structures contributing most significantly to the development of Bonnet Plume Basin were the Knorr and Deslauriers faults (Fig. 3.13; Norris and Hopkins, 1977) of the Richardson Fault Array. Displacement on them in post-Paleocene time resulted in relative uplift of the outer blocks within the array and relative depression of the inner blocks to preserve Bonnet Plume Formation in the core of the array.

One of the most striking features of Bonnet Plume Basin is its interruption of some east-trending structures heading into it from the Mackenzie and Taiga–Nahoni foldbelts, and the apparent continuity of south-trending fault blocks comprising Richardson Anticlinorium beneath it (Norris, 1982a). In the Taiga Ranges, for example, the more northerly or frontal folds and fault blocks terminate abruptly at Deslauriers Fault and do not continue eastward across it into

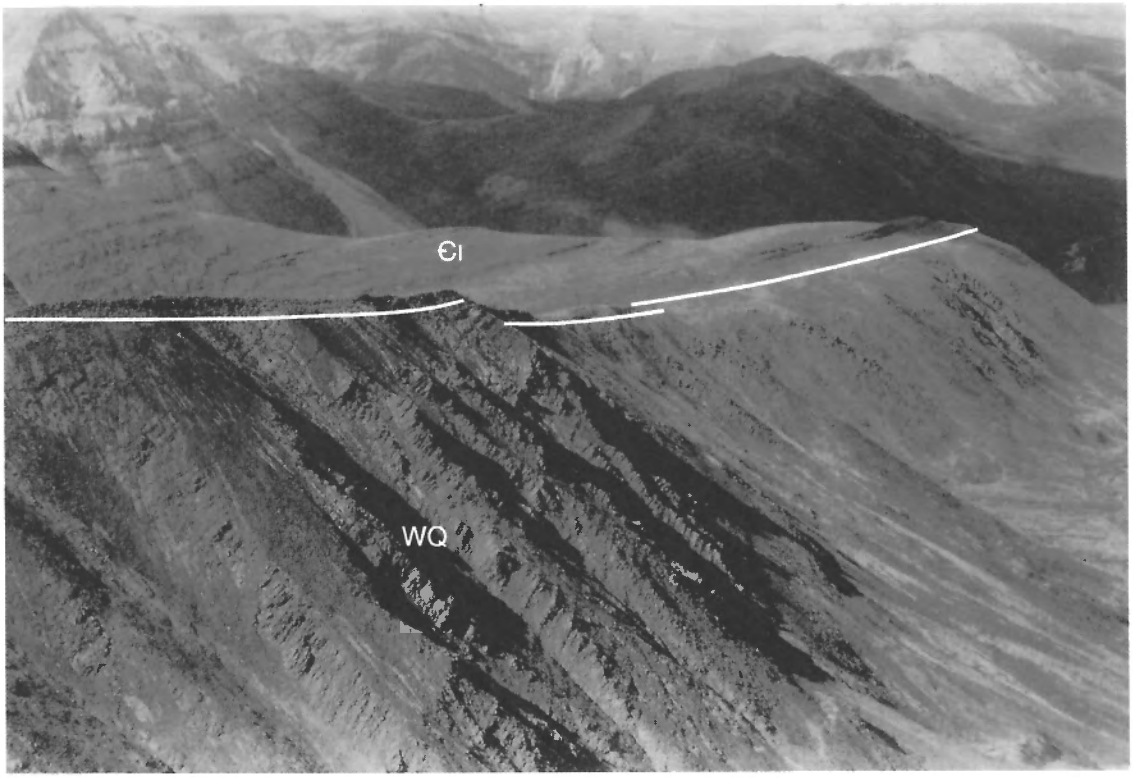

Figure 3.11. *Angular unconformity between slaty argillite and quartzite of the Werneckian Quartet Group (WQ) and basal sandstone of the Franklinian Illtyd Formation (€l) at GSC Section 106E3a (Chapter 5) at headwaters of Illtyd Creek, northern Wernecke Mountains, Wind River map area, Yukon Territory. ISPG photo 1860–2, looking west.*

Bonnet Plume Basin. Similarly, west-trending folds and high-angle faults in the northwest corner of Mackenzie Foldbelt are truncated by Knorr Fault along the east boundary of the basin. Farther south, in the vicinity of the 65th parallel, however, folds and faults in Ogilvie Mountains swing southeast into line with the trend of the anticlinorium and are clearly structurally west of (behind) Mackenzie Foldbelt.

The apparent continuity of major strands of the Richardson Fault Array from north to south on the flanks as well as beneath Bonnet Plume Basin, on the other hand, emphasizes the fundamental role of the array in isolating Mackenzie Foldbelt from the remainder of the Columbian Orogen.

Taiga–Nahoni Foldbelt (15)

Taiga-Nahoni Foldbelt comprises the west- and north-trending fold bundles of the Taiga and Nahoni Ranges respectively. It forms the deep recess (King, 1969, p.66) in the mountain front of northern Yukon Territory between the great arc of Mackenzie Mountains to the east and the Brooks Range of northern Alaska. The recess is herein termed the Ogilvie Reentrant and the abrupt change in direction of the mountain front, the Ogilvie Deflection (Fig. 3.15; Norris, 1985a). The foldbelt is flanked on the east by Richardson Anticlinorium, on the south by Selwyn Basin, on the west by Kandik Basin, and on the north and east by the Aklavik Arch Complex and Eagle Foldbelt.

Like Mackenzie Foldbelt, folds are the dominant structural feature. They are commonly cut by contractional, strike faults that verge either toward or away from the mountain front (Fig. 3.16). Their axial surfaces may be vertical or steeply dipping, as in the Mackenzie and Selwyn foldbelts. There is, therefore, no preferred direction of vergence like that seen in the Frontal Belt of southern Canada.

From east to west in the Taiga Range, the anticlines and synclines are preferentially arranged left-hand en echelon, similar to those along the west-trending leg of Mackenzie Foldbelt. The mountain front steps systematically to the left or southward (Fig. 3.1). At the headwaters of Ogilvie River, in the deep recess in the mountain front, the foldbelt turns abruptly

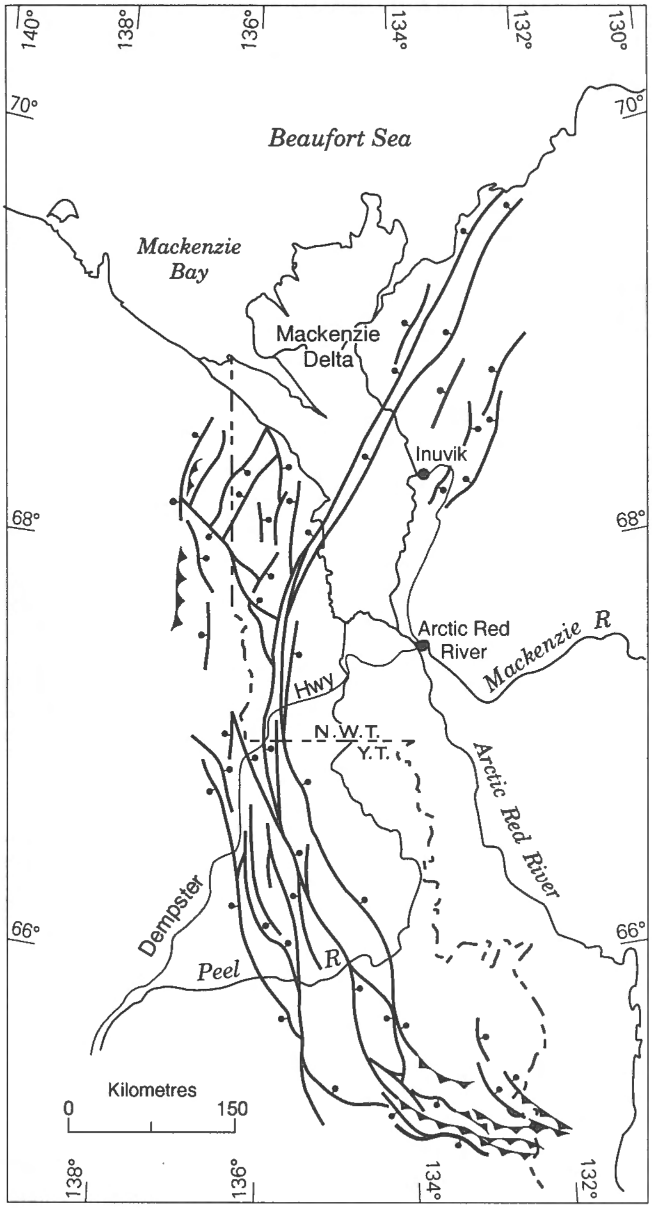

Figure 3.12. *Richardson Fault Array, northern Yukon Territory and western Northwest Territories. Faults are shown as heavy, solid lines with solid dots on the downthrown walls. Contraction faults have teeth on the hanging walls. The array extends from northern Mackenzie Mountains to the continental shelf of southern Beaufort Sea.*

through more than 90° and continues in the Nahoni Range, trending first northeastward, then northward, and finally northwestward (Norris, 1982b). Right-hand en echelon folds predominate in this north-trending leg. Around the recess, therefore, is a reversal in configuration of fold axes that is a mirror image of that observed around the Mackenzie Deflection (Norris, 1974).

One of the most important structures associated with the foldbelt is Yukon Fault (Fig. 3.17) on its west flank. It is traceable for about 420 km between the Kaltag and Tintina faults. At its northern extremity it merges asymptotically with the Kaltag Fault (Norris, 1985a). Southward it traces out a giant "S". It crosses Porcupine River 10 km downstream from the mouth of Driftwood River, transects the Aklavik Arch Complex on the southeast flank of Dave Lord Uplift, and trends southwest in the valley of Salmon Fork River. It then weaves back and forth across the international boundary with Alaska, reentering Canada as it crosses Jungle Creek at latitude 65°29′N to form a major tectonic salient at the drainage divide between Ettrain Creek and Tatonduk River, and then swinging southwest to exit Canada at the headwaters of Harrington Creek. It is truncated and offset 15 km right laterally on Hardluck Fault in east-central Alaska (Brabb and Churkin, 1969), then continues southwest about 40 km, with Michigan Creek Anticline in its immediate footwall for part of the way. Finally it joins asymptotically with Tintina Fault in the vicinity of Washington Creek (op. cit.).

Yukon Fault attains maximum stratigraphic separation in the Ogilvie Deflection with the Proterozoic Tindir Group resting upon the upper Cretaceous Monster Formation (Fig. 3.17; Norris, 1982b). There, it has all the attributes of a classical thrust fault. However, to both the north and south, the separation appears to change abruptly and unpredictably, suggesting truncation and displacement of preexisting structures. The truncation, folding and faulting of the Monster Formation beneath it, moreover, indicates that major displacement on the fault took place in Late Cretaceous or younger times, possibly associated with Laramide compression.

Kandik Basin (14)

Kandik Basin in Canada is the small area underlain by the Albian? Kathul Formation, a thick, monotonous succession of conglomerate and sandstone straddling the Yukon/Alaska border at the headwaters of the Nation and Kandik rivers (Norris, 1982b). It is elongated to the southwest so that by far the largest part of the basin is in Alaska (Churkin and Brabb, 1969).

Kandik Basin is a structural depression on the west flank of the Nahoni segment of the Taiga-Nahoni Foldbelt. Its southeast flank is a depositional contact as far south as Jungle Creek, where it is repeated on a major, east-verging thrust fault. At its southwest extremity it swings abruptly subparallel to Tintina Fault, suggesting right-hand drag along the fault

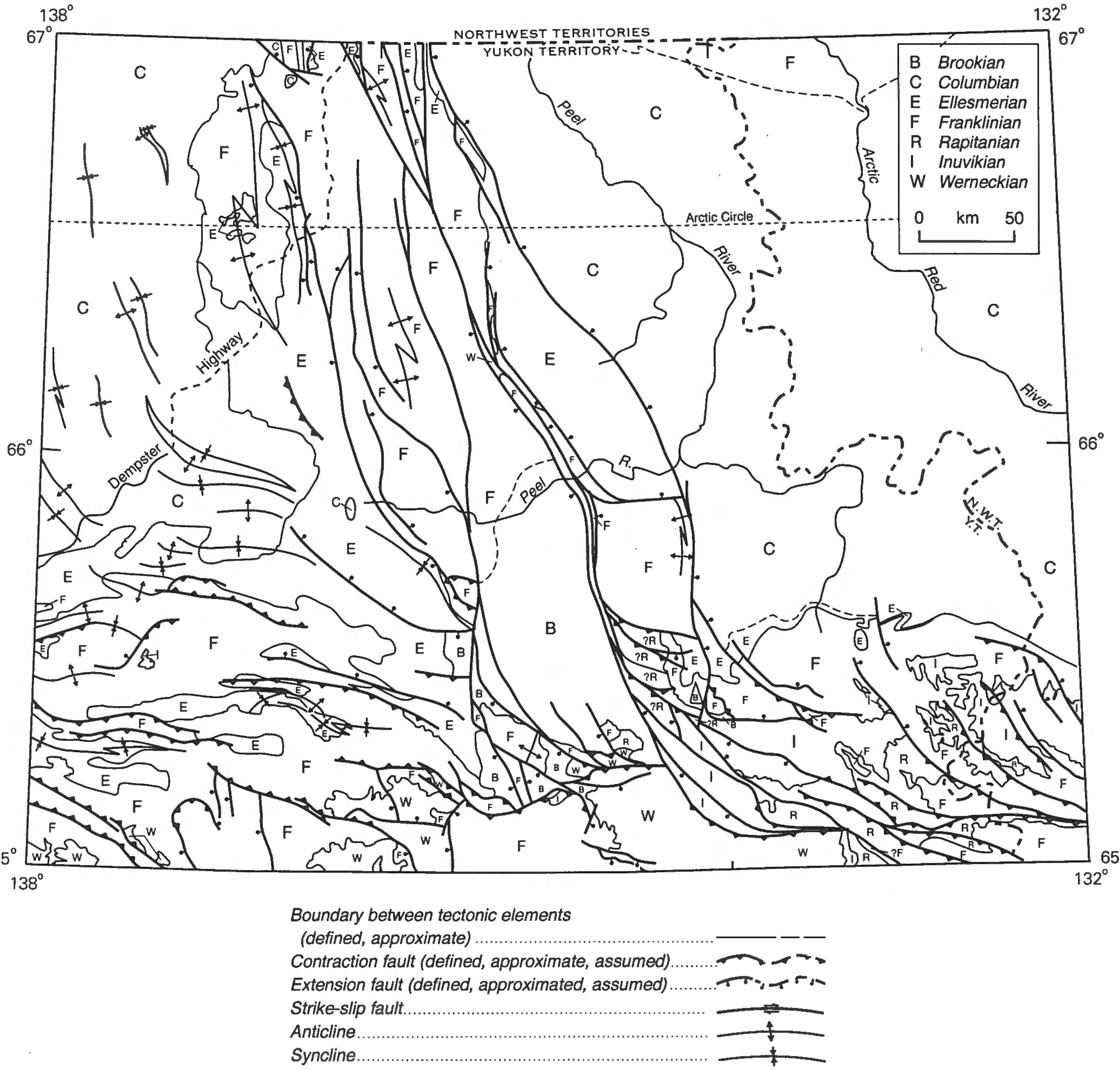

Figure 3.13. *Intersection of Taiga–Nahoni and Mackenzie fold belts with Richardson Anticlinorium, northern Yukon Territory (after Norris, 1985a). Note that south-trending, subvertical strands of Richardson Fault Array are transformed into contraction faults in northern Mackenzie Mountains, implying that the two types of faults were synkinematic. Those comprising Richardson Fault Array may have had dextral slip on them in the early Tertiary while thrusting was taking place in Ogilvie, Wernecke and Mackenzie Mountains. Lithologic assemblages are grouped according to sequence (Table 3.1).*

(Churkin and Brabb, 1969, p. 105). The northwest flank of the basin is delimited by the Aklavik Arch Complex. There, the Kathul and older rocks in the basin have been structurally depressed on an array of northeast-trending, subvertical faults (c.f. Mardow Creek Fault; Brabb and Churkin, 1969). Its northeast extremity in Canada, at the headwaters of Orange Creek, is also fault-bounded. There, the Kathul is depressed against Carboniferous and younger formations (Norris, 1981b, 1982b).

Internally, little is known about the structure of Kandik Basin except that it is very complex (Churkin and Brabb, 1969). Step Mountains Anticline (Brabb and Churkin, 1969), cored at the surface with Upper Devonian Nation River Formation, is a prominent

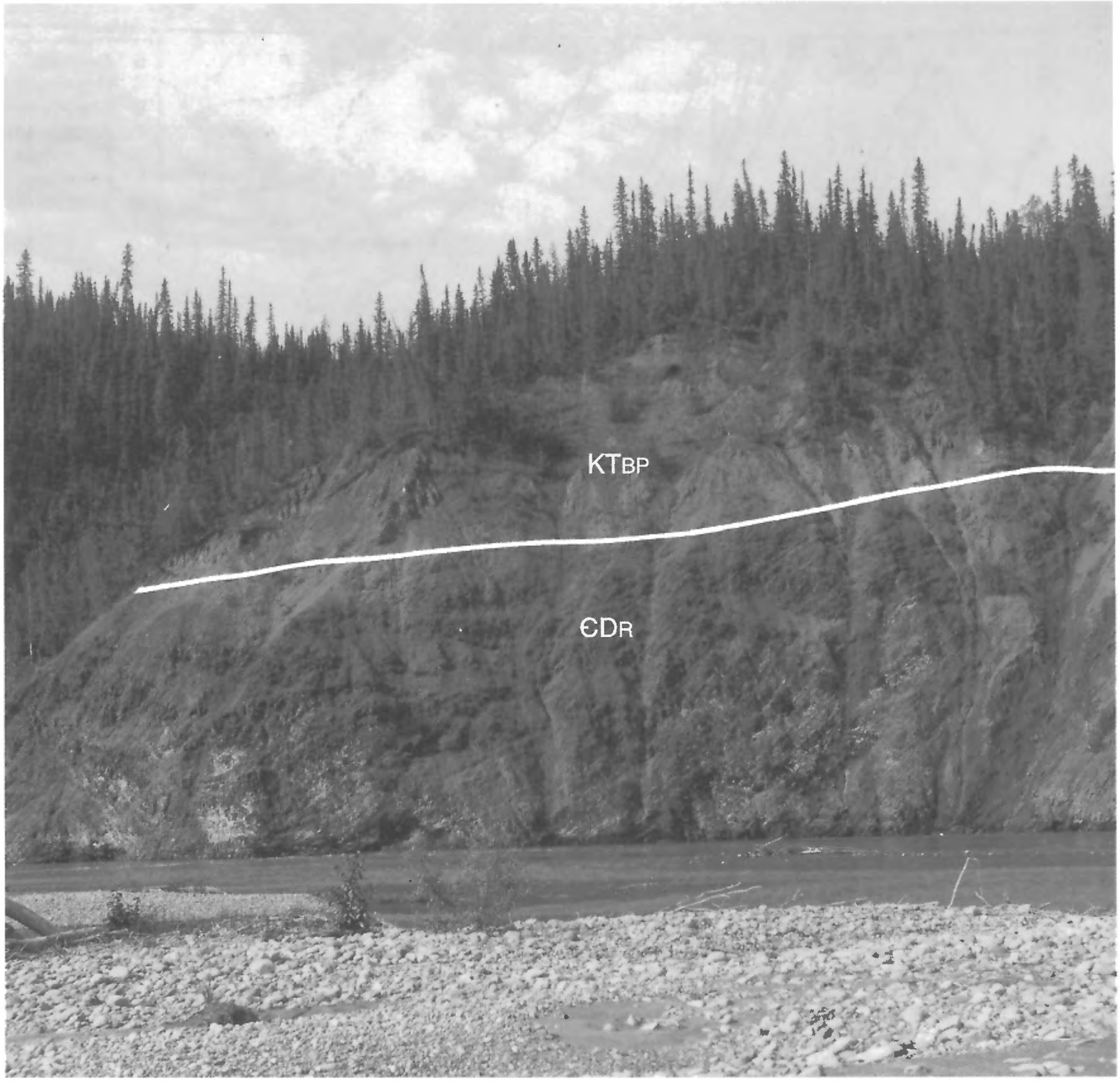

Figure 3.14. *Angular unconformity between faulted and folded lower Paleozoic Road River Formation (ЄDR) and gently inclined Late Cretaceous Bonnet Plume Formation (KTBP) on the left bank of lower Wind River, Wind River map area, Yukon Territory. The Road River is considered to have been deformed during the Columbian Orogeny and the whole to have been uplifted and tilted in the Laramide. GSC photo 1991–57.*

structural high close to the southeast boundary of the basin in Alaska. Farther northeast in Canada, at the headwaters of Kandik River, resistant Lower Cretaceous quartzites outline northeast-trending folds along strike with the Step Mountains Anticline and suggest the presence of both large- and small-scale folds in the interior of the basin at diverse structural levels. On the southeast flank of the basin, moreover, the Kathul(?) is closely folded along with older formations in the Taiga–Nahoni Foldbelt (Norris, 1982b).

Kandik Basin, as a structurally controlled depositional site, must have developed in Albian, the presumed age (Brabb, 1969) of the Kathul sediments. It appears to have been a precursor of the early Late Cretaceous Columbian Orogeny and to have been concurrent with the development of Rapid Depression north of the Aklavik Arch Complex. It may be, therefore, slightly older than the Bonnet Plume and Eagle Plain basins, synorogenic downwarps (exogeoclines) associated with the Columbian event.

Eagle Foldbelt (16)

Eagle Foldbelt lies within the deep reentrant of Taiga–Nahoni Foldbelt (Fig. 3.14). It is flanked on the east by the Richardson Anticlinorium and truncated on

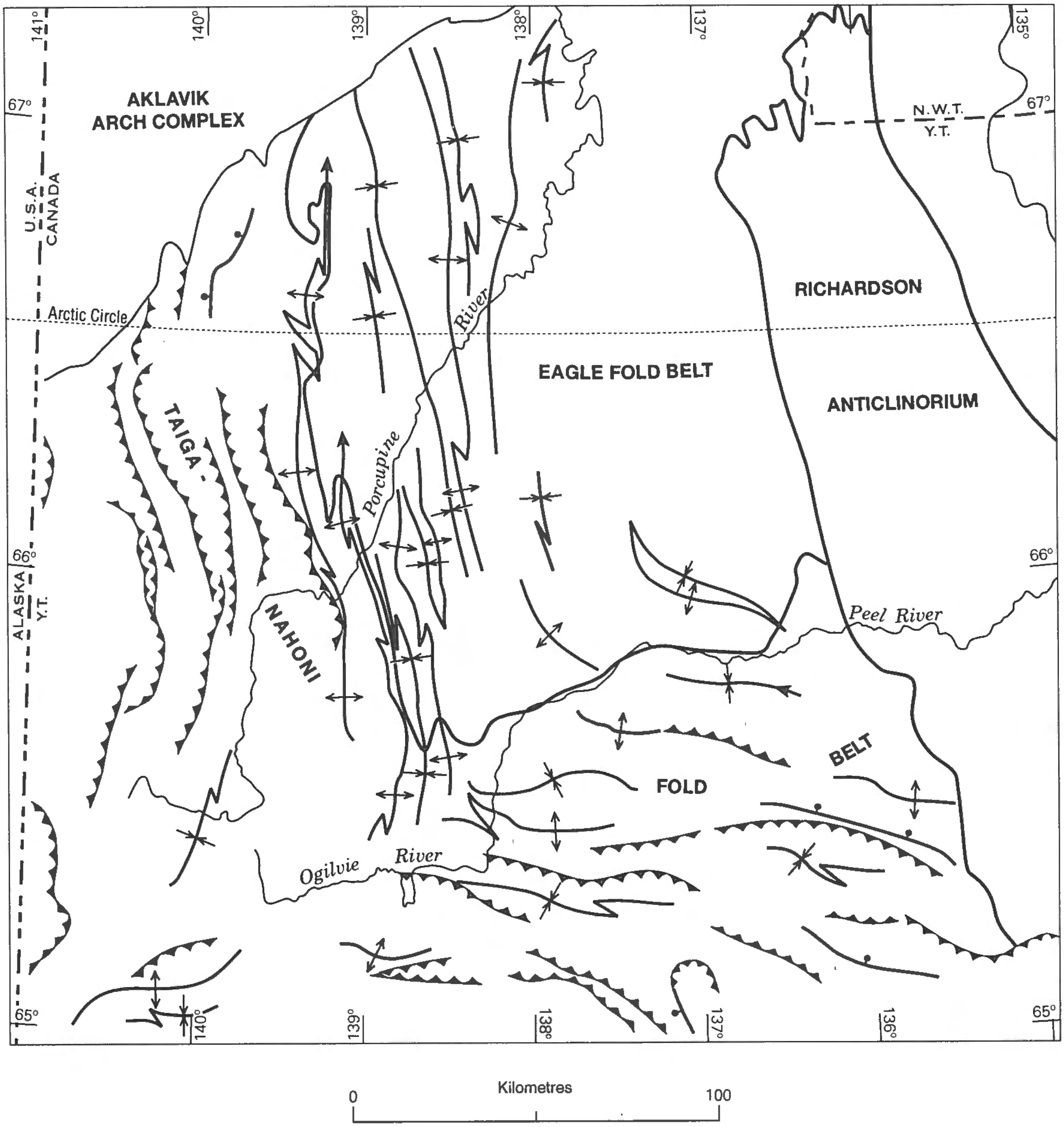

Figure 3.15. Ogilvie Deflection in the Taiga–Nahoni Foldbelt, northern Yukon Territory (after Norris, 1985a). The structural grain of the Frontal Belt is continuous as it turns abruptly from west- to north-trending at the headwaters of Ogilvie River, and the folds change from left- to right-hand en echelon arrays from the Taiga to the Nahoni Ranges. Sufficient contraction faults, anticlines and synclines are included to display the abrupt change in strike of the structural grain around the deflection. The boundary between the Taiga–Nahoni Foldbelt and adjacent tectonic elements is shown as a heavy solid line.

the north by the Aklavik Arch Complex. Upper Cretaceous sandstone and shale of the Eagle Plain Group are widespread at the surface in the central and western portions of the foldbelt and their zebra-striped pattern of light and medium grey units outlines the gently folded nature of the terrain. Middle and late Paleozoic clastics are widely exposed in the southeast corner of the area adjacent to Richardson Anticlinorium.

Folds in Eagle Plain generally trend slightly west of north. Some (c.f. Whitestone Syncline; Norris, 1981b) are up to 120 km long. They are most commonly symmetrical and open. The few that are asymmetrical verge gently westward, with steeply east-dipping axial surfaces. Many of the folds lie right-hand en echelon to one another to conform with those in the north-trending leg of the Taiga–Nahoni Foldbelt and with the regional pattern of alternating right- and left-hand configurations in fold bundles outlining the eastern flank of the Cordilleran Orogenic System of northern Canada (Norris, 1972a). Some of the folds are cut by east- or west-dipping contraction faults of lengths generally less than 30 km and with stratigraphic separations less than the thickness of the Eagle Plain Group (760 m).

The roughly rectangular structural depression, like the Kandik Basin, appears to have undergone at least two episodes of deformation. First it was compressed to give rise to folds and contraction faults as the Laramide Orogeny overran it in the Late Cretaceous. These structures were then truncated by faulting associated with differential uplift of the Aklavik Arch Complex in the early to mid-Tertiary.

A major sub-Upper Cretaceous unconformity systematically truncates Upper Devonian through Lower Cretaceous formations from north to south across the foldbelt on the south flank of Eagle Arch. Like the formations above and below it, the unconformity is folded so that updip truncation of porous Carboniferous sandstones at the unconformity provides structures favorable to the entrapment of hydrocarbons (Graham, 1973; Norris, 1985b; Chapter 15).

Aklavik Arch Complex (5–13)

Aklavik Arch Complex is a composite, northeast-trending array of commonly elongate subelements extending from the Tintina Fault in eastern Alaska, 800 km beyond the northeast limit of Tuktoyaktuk Peninsula in Northwest Territories. There it plunges beneath the continental shelf of southern Beaufort Sea. From southwest to northeast it embraces an unnamed structural high in Alaska that appears to be the continuation of Keele Block in Canada, Dave Lord, White, Rat, Scho and Cache Creek uplifts, Canoe

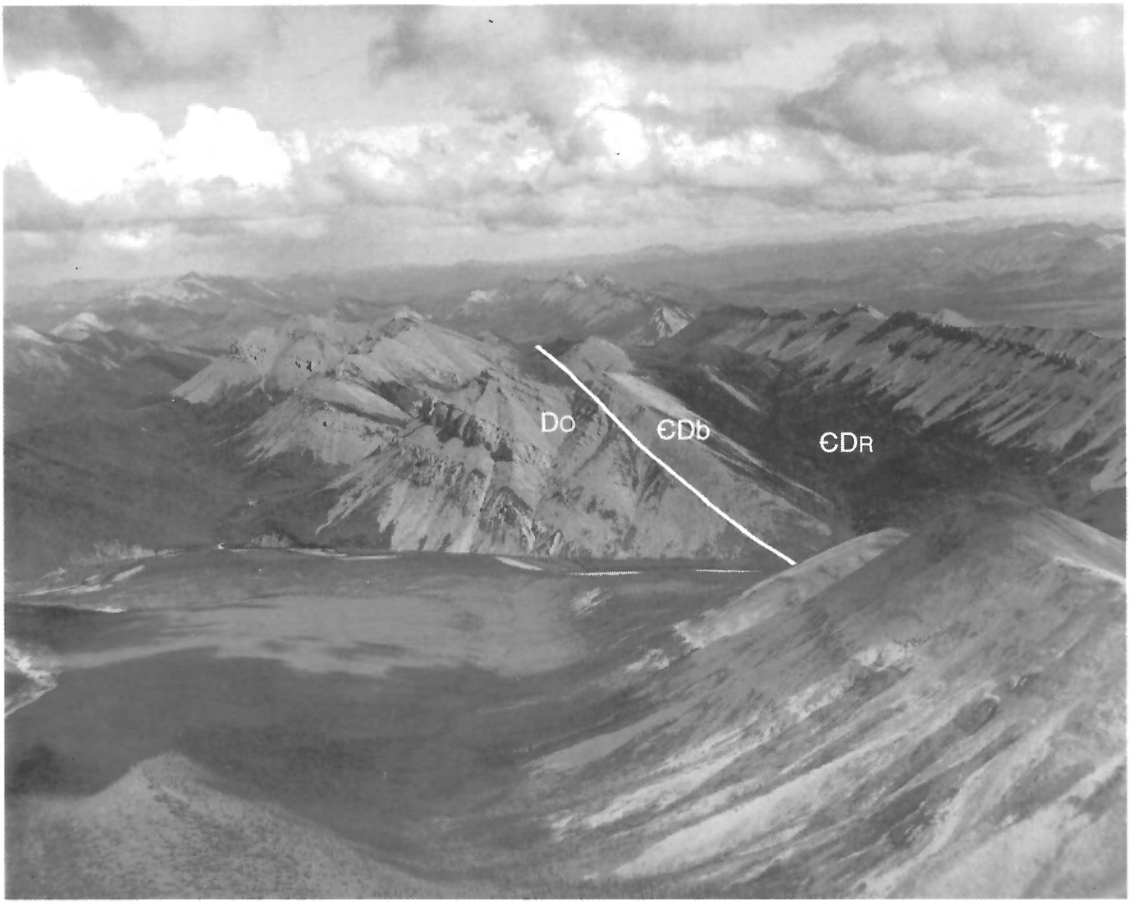

Figure 3.16. *South-dipping thrust fault in Taiga Ranges immediately east of Blackstone River at GSC Section 116H6, Hart River map area, Yukon Territory. Unnamed lower Paleozoic carbonate rocks* (ЄDb) *and Road River Formation* (ЄDR) *are thrust over Lower and Middle Devonian Ogilvie Formation* (DO). *GCS photo 1584–78, looking east.*

Depression and Campbell Uplift (Fig. 3.1). Individually the long directions of these uplifts and depressions trend approximately 25° counterclockwise from the long axis of the arch complex so that the subelements are arranged, for the most part, in a systematic, right-hand en echelon pattern. This is the basic internal structure of the complex. Collectively the complex trends northeast, oblique to the regional structural grain of the northern part of the Frontal Belt of the Cordilleran Orogenic System and subparallel to McDonald Fault in the Interior Platform, well to the southeast of the project area.

The rocks comprising the Aklavik Arch Complex range from Proterozoic to Tertiary, although the successions in the various subelements are by no means complete (Norris, 1983a). Many unconformities, some spectacularly angular, are present in the complex and attest to intermittent and prolonged activity. In northern Keele Block, for example, Werneckian(?) clastics are overlain by Middle Cambrian and younger Paleozoic carbonates and clastics, indicating prolonged and deep erosion of the supracrustal wedge in the middle and late Proterozoic. Similarly, in Campbell Uplift at the northeast end of the exposed complex, Inuvikian carbonates and clastics are overlain with angular unconformity by Franklinian rocks.

Keele Block (5)

Keele Block (Fig. 3.1) is made up largely of uplifted, folded and faulted Precambrian and Paleozoic sedimentary, volcanic and intrusive rocks. In Canada it is bounded by the Kaltag Fault on its northwest flank and by the Yukon Fault on its southeast flank. Gently folded, fault-bounded panels of lower, middle and upper Paleozoic strata comprising Keele Range strike northeast from Alaska toward Porcupine River where they disappear. There they are either removed at the sub-Upper Cretaceous unconformity or they pass laterally into shale along the flared northern margin of the Richardson Trough (Norris and Yorath, 1981). Southwestward in Alaska they give way to Werneckian clastics and chert at the headwaters of Salmon Fork River (Brabb, 1970) and in turn, to a highly folded and faulted, mixture of Precambrian, Paleozoic and Mesozoic rocks (Brabb and Churkin, 1969) adjacent to

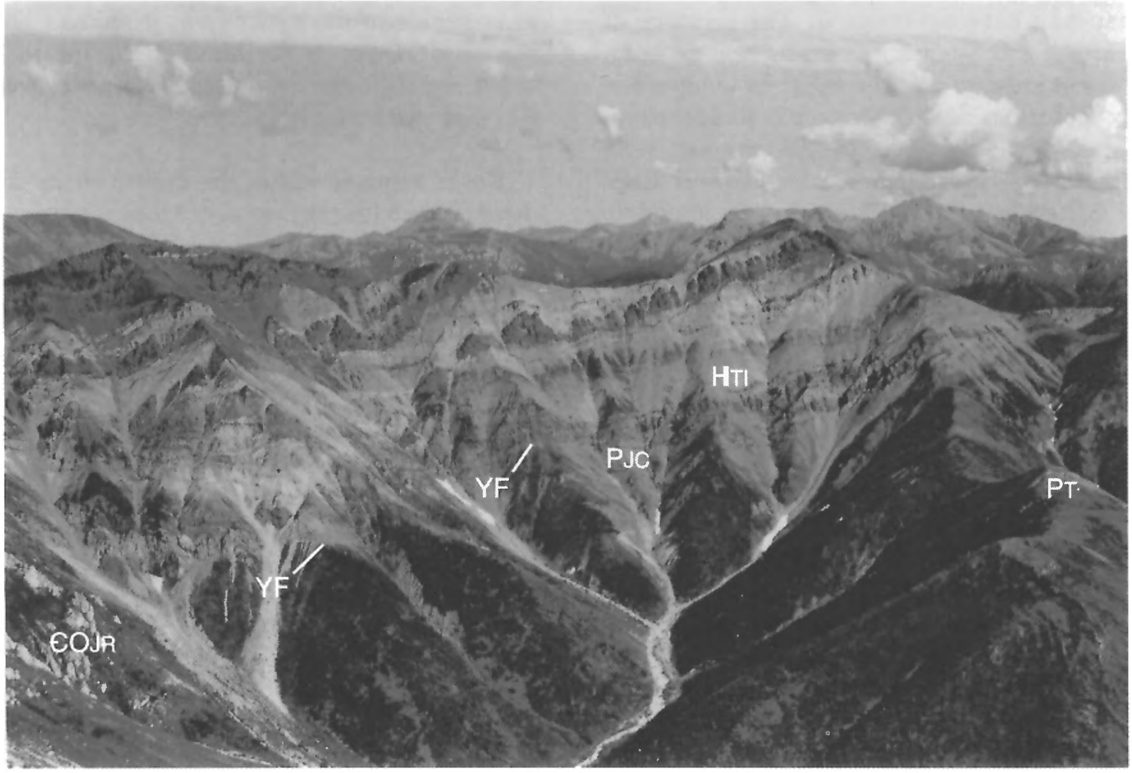

Figure 3.17. Yukon Fault (YF) *at the headwaters of Harrington Creek, Ogilvie River map area, Yukon Territory. Note the faulted mafic sills in undivided Tindir Group* (HTI) *in the immediate hanging wall of the fault. Highly deformed Cambro-Ordovician Jones Ridge Formation* (ЄOJR) *and Permian Jungle Creek* (PJC) *and Tahkandit* (PT) *formations make up the footwall at this locality. ISPG photo 3590–6.*

the Tintina Fault. The folds in Alaska strike almost due east and are arranged left-hand en echelon.

Keele Block is gently "S" shaped in plan as it terminates against the Kaltag and Tintina faults at its northern and southern extremities respectively. The shape is suggestive of right-hand drag against these major, strike-slip discontinuities in the supracrustal wedge. Moreover, the left-hand en echelon array of folds adjacent to Tintina Fault is a consistent dynamic response to north–south compression with dextral slip in the one shear direction (Tintina Fault) and sinistral folding in the conjugate direction.

Dave Lord Uplift (6)

Dave Lord Uplift is an irregularly faulted and folded assemblage of Werneckian to Columbian sedimentary and volcanic rocks, bounded on the northwest by the Yukon Fault and on the southeast by the Dave Lord Fault. Regionally it is tilted toward the northeast so that the oldest rocks are exposed at its southwest extremity. Reconnaissance mapping would suggest that there are no obvious fold linkages or fault arrays from which to deduce the direction and sense of shear couples that may have deformed it. The presence of both contraction and extension faults as well as folds, however, would indicate that the uplift has undergone a complex deformational history of compression, extension and strike-slip. The angular unconformity between deformed lower Paleozoic, Road River shale and Lower Cretaceous, Sharp Mountain conglomerate, exposed where the uplift crosses Porcupine River, is supporting evidence that the Ellesmerian Orogeny uplifted and deformed this segment of the Frontal Belt of the Columbian Orogen (Knipping, 1960).

Canoe Depression (11)

Canoe Depression is a structural low extending from the northwest corner of Eagle Foldbelt to the continental shelf beyond Tuktoyaktuk Peninsula[1]. Within it is a mosaic of structural highs, including Cache Creek, White, Rat, Scho and Campbell uplifts. On its southeast flank it is bounded by the Eagle Foldbelt and northern Interior Platform. Its northwest flank is shared by Dave Lord Uplift and Rapid Depression. The trace of fold axes and faults within it are characteristically curvilinear. Some parallel the long direction of the depression, others cross it. Like those in Dave Lord Uplift on its northwest flank, the folds (Fig. 3.18) and faults lack great length and continuity. They demonstrate truncation and offset of earlier structures to give the internal fabric of the subelement a shredded appearance and to reveal a very complex history of compression and extension both across the element and along it.

Cache Creek Uplift (8)

Cache Creek Uplift is a northeast-trending structural high within Canoe Depression, straddling the boundary between Yukon Territory and Northwest Territories (Norris and Young, 1978). It owes its present form to mid-Tertiary or younger differential uplift, although it has clearly been tectonically active at least since the mid-Paleozoic. It trends approximately 25° counterclockwise from the long axis of the Aklavik Arch Complex.

The uplift is fault-bounded on at least three sides (Fig. 3.19). On the northwest is Eagle Fault, and on the southwest, Cache Creek Fault. Canoe Fault cuts the southeast flank of the uplift and Beaver Fault truncates at least part of the structure as it plunges beneath the Mackenzie Delta in the direction of the thick Cretaceous and Tertiary clastic sequence beneath Kugmallit Bay and Richards Island.

Rocks exposed within the uplift, on its flanks and downplunge range in age from at least Middle Devonian to early Tertiary. In the core, inclined and faulted, Middle Devonian or older, massive carbonates are overlain with angular unconformity by Carboniferous and Permian limestone and sandstone (Fig. 3.20; Nassichuk and Bamber, 1978). Like Dave Lord Uplift along Porcupine River, the deformation and bevelling of these Franklinian core rocks doubtless document the effects of the Ellesmerian Orogeny.

The Ellesmerian and Columbian sequences are represented by unnamed upper Paleozoic formations overlain disconformably by Jurassic and Cretaceous shales and sandstones on the northwest flank of the uplift (Fig. 3.21). In turn, the Laramidian sequence is preserved downplunge on the north flank (Fig. 3.8).

The internal structure of the uplift consists of faults and folds representing the cumulative effects of deformation beginning at least with the Ellesmerian. Except for local reversals associated with folds, the panels of Carboniferous and younger rocks dip generally to the northwest and southeast away from the culmination of the uplift at the headwaters of Little Fish Creek. The

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[1] In this account, the Kugmallit Depression (Young et al., 1976) adjacent to Tuktoyaktuk Peninsula is incorporated within the Canoe Depression.

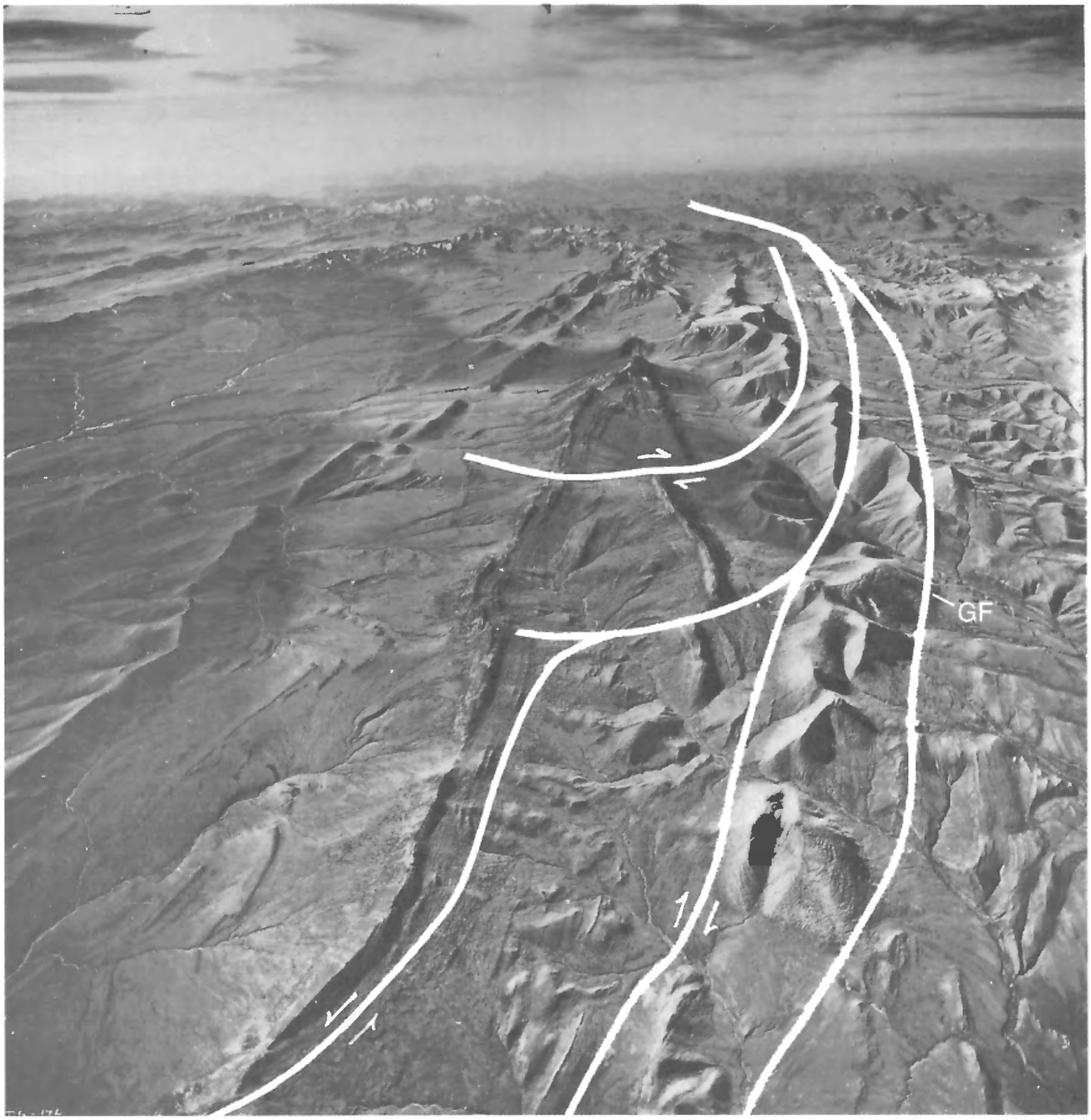

Figure 3.18. South-plunging Gilbert Anticline in northern Richardson Mountains, Blow River and Davidson Mountains map area, Yukon Territory. The northern half of the fold, exposing Jurassic and Lower Cretaceous clastic rocks, is broken up by transverse faults. Gilbert Fault (GF) *truncates its west flank. NAPL oblique photo T6–17L, looking south.*

panels are cut into a series of elongate blocks by a family of northeast-trending, nearly vertical, curviplanar faults. Vertical displacements differentially elevated the blocks closest to the axis of the uplift in the mid-Tertiary or later. Of particular interest is Castle Fault (Fig. 3.19) because it documents some of the earlier deformational history of the uplift. Immediately west of the fault, the Upper Cretaceous Tent Island Formation rests with right angular unconformity upon rocks as old as Jurassic; and immediately east of it the succession is nearly complete from the Late Cretaceous Tent Island down to the Jurassic Bug Creek Formation. Clearly there was deformation, uplift and truncation of the Jurassic and Cretaceous succession on the northwest flank of the uplift in the mid-Late Cretaceous. It took place after deposition of the early Late Cretaceous Boundary Creek Formation and prior to deposition of the Maastrichtian Tent Island Formation.

White Uplift (7)

White Uplift (Chapter 13) in northern Richardson Mountains, embraces a small, isolated mass of car-

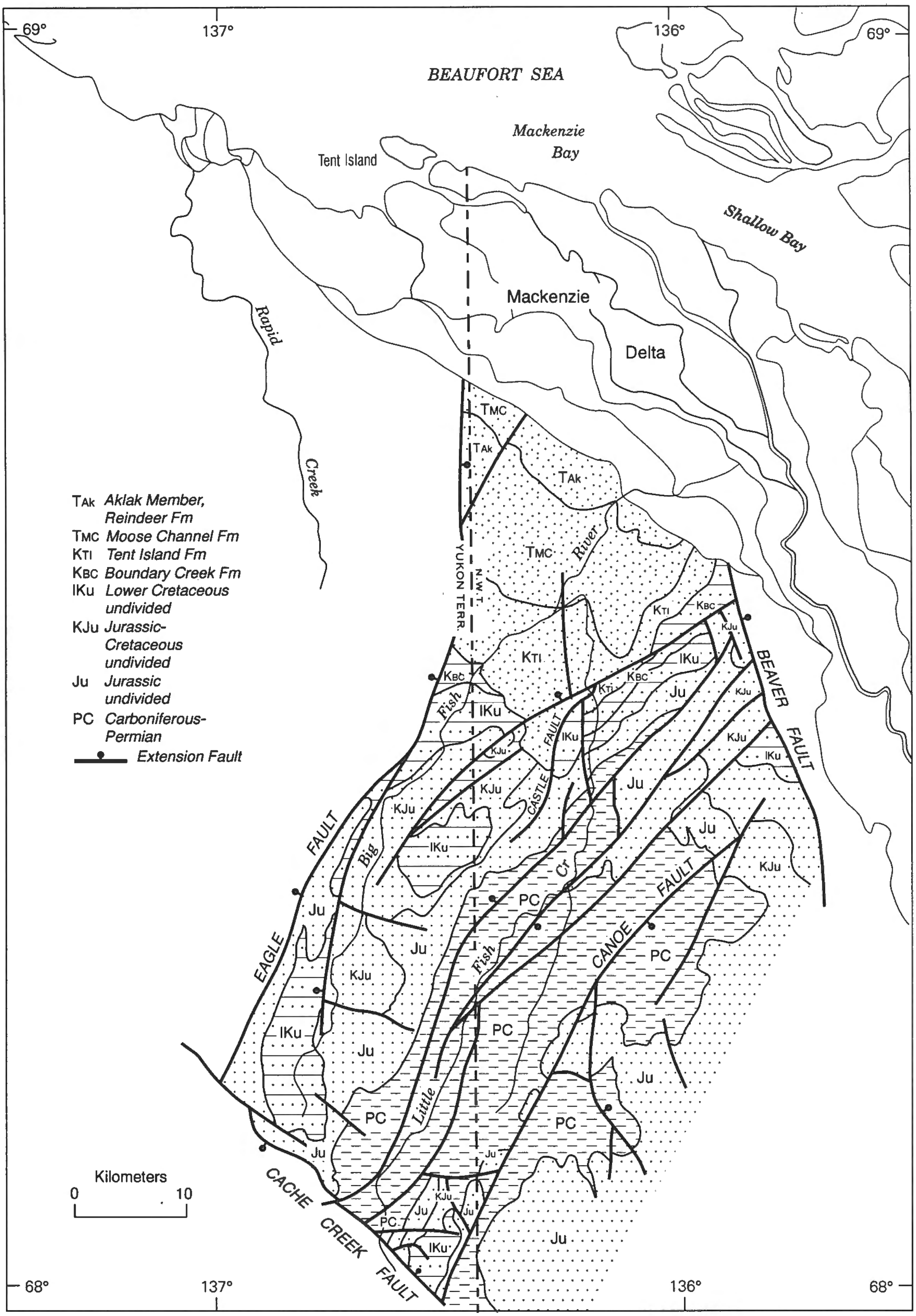

Figure 3.19. *Detailed geological map of Cache Creek Uplift, Yukon Territory and Northwest Territories, showing bounding faults as well as prevailing northeast-trending structural grain characterizing the Aklavik Arch Complex. The rocks range in age from Middle Devonian or older in the core to early Tertiary on the north plunge of the structure beneath Mackenzie Delta.*

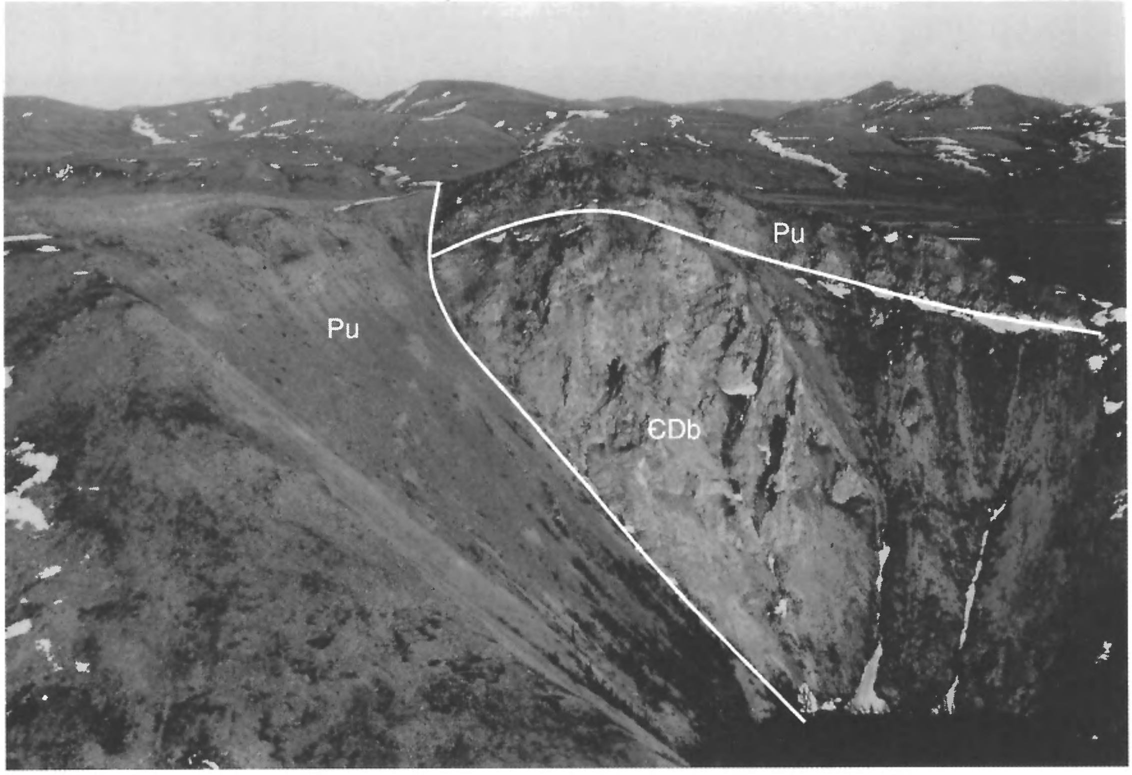

Figure 3.20. *Faulted angular unconformity between limestone* (ЄDb) *of Middle Devonian or older age and Lower Permian limestone and sandstone* (Pu) *in the core of Cache Creek Uplift. GSC Section 117A8. The section is exposed on an unnamed tributary to Little Fish Creek, Blow River and Davidson Mountains map area, Yukon Territory. The deformation of the core rocks appears to have been Ellesmerian and caused by north–south compression, consistent with observations in Rat Uplift (Figs. 3.23, 3.24). ISPG photo 1860–33, looking east.*

bonates and clastics ranging in age from Precambrian to Permian. It is fault-bounded and tilted gently to the east so that the oldest rocks are exposed on the west flank and the youngest on the east (Fig. 3.22). Within the uplift, unconformities are known at the base of the Lower Cambrian, Middle Cambrian, Upper Silurian, Upper Carboniferous and Permian. The one at the base of the exposed Phanerozoic section is angular and, along with homotaxial unconformities in Keele Block and Campbell Uplift, it identifies a major, regional deformational event in the late Precambrian (Cook, 1988), at least along the axis of the Aklavik Arch Complex. All the other hiatuses are disconformities. Of particular interest is the one at the base of the Upper Carboniferous Wahoo Formation, because it identifies the Ellesmerian Orogeny. It reveals that compression associated with that event had little effect beyond differential uplift and depression on the predominantly carbonate succession comprising the block.

Rat Uplift (10)

Rat Uplift straddles the boundary between Yukon Territory and Northwest Territories at the headwaters of Bell River. As defined originally (Norris, 1973) it included Scho Uplift along strike to the northeast but separated by the Fish Creek Fault. Insofar as these two subelements played separate roles in the evolution of Canoe Depression, at least as far back as the Ellesmerian event, they are herein considered structural entities. Both lie on the southeast flank of the depression.

The exposed stratigraphic succession in the uplift ranges from the Upper Devonian Imperial Formation to the Jurassic Bug Creek Group (Norris, 1981c). A regional, angular unconformity (Fig. 3.23) separates the Permian from the Upper Devonian and identifies the Ellesmerian Orogeny. A second regional unconformity at the base of the Bug Creek Group cuts downsection through the Permian so that, at least

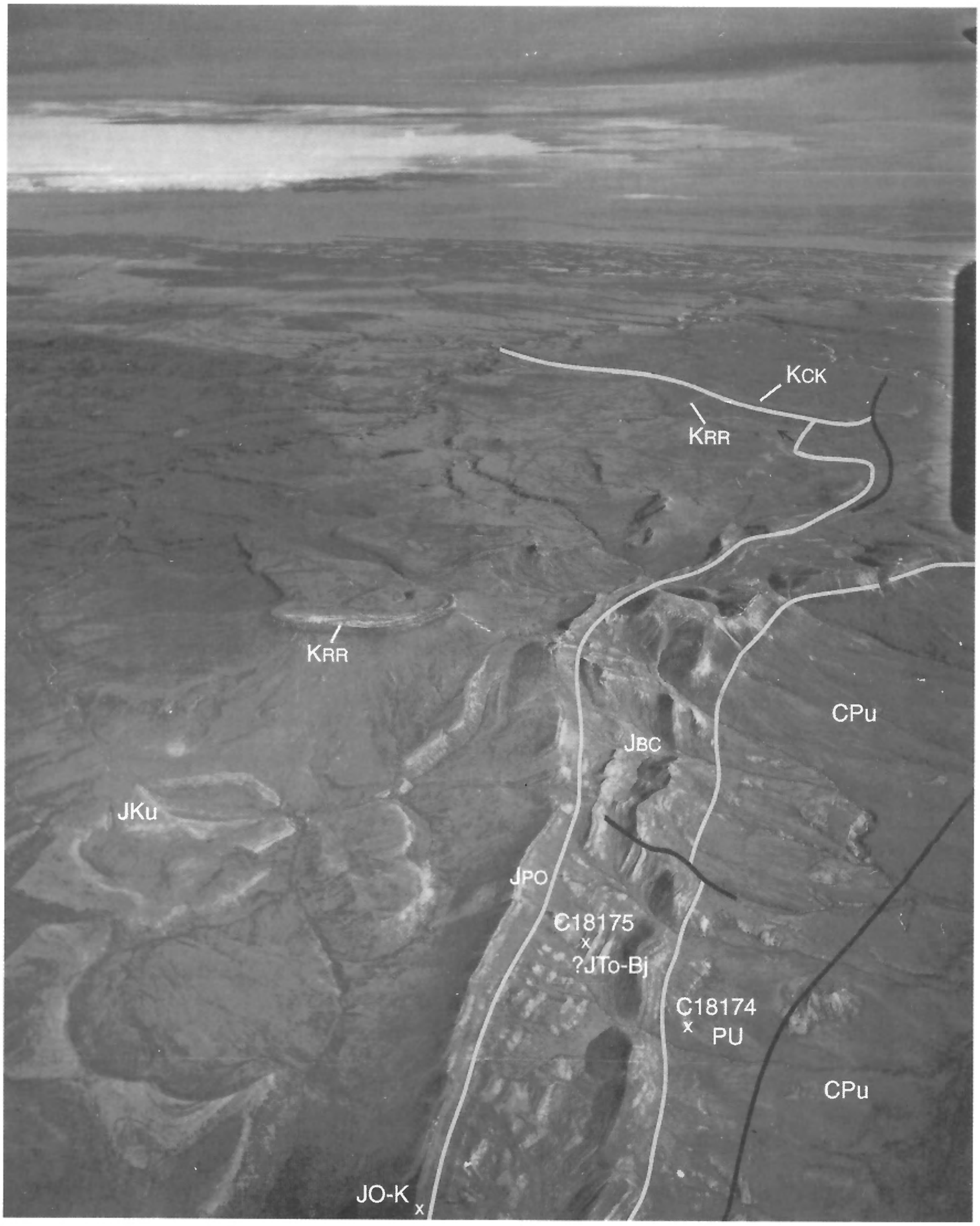

Figure 3.21. *Northwest flank of Cache Creek Uplift at GSC Section 117A5, Blow River and Davidson Mountains map area, Yukon Territory. Stratigraphic units are identified by system and formation: Cuesta Creek Member of Tent Island Formation* (KCK); *Rat River Formation* (KRR); *Jurassic and Lower Cretaceous, undivided* (JKu); *Porcupine River Formation* (JPO); *Bug Creek Formation* (JBC); *Carboniferous and Permian, undivided* (CPu). *Positions of three GSC fossil localities (x) are also shown. NAPL oblique photo T5–22R, looking north.*

locally, Jurassic clastics rest upon the Upper Devonian Imperial Formation (op. cit.).

Rat Anticline is the principal fold in the uplift. It trends northeast, parallel to the long direction of the subelement and to the Ellesmerian folds (Fig. 3.24) within it. The anticline lies centrally within a left-hand en echelon array of large-scale folds, with an orientation which appears to have been preordained by the Ellesmerian deformation. Refolding of beds involved in the Ellesmerian Orogeny, along with Permian and younger formations, probably took place in the Columbian compressional event in the early Late Cretaceous. The deduction is that the left-hand array identifies an ancestral, northeast-trending, left-hand shear couple that was a result of north–south compression during the Ellesmerian event. Mesoscopic folds in the Imperial Formation (Fig. 3.24), therefore, would be expected to be arranged left-hand en echelon.

Northwest-trending Fish Creek Fault appears to be the conjugate Ellesmerian structure to Rat Anticline, reactivated in the Columbian(?) Orogeny. Initial displacement on the fault resulted in elevation of its northeast wall so that the Upper Devonian clastic succession was stripped from it in Scho Uplift, whereas the succession was preserved southwest of the fault in Rat Uplift. The fault, as mapped, appears to be located and oriented approximately over its Ellesmerian (and other?) precursor. It is not necessarily a simple extension to higher structural levels caused by Columbian compression and, concomitantly, it may lack the continuity and lateral extent of its ancestor because of later deformation.

Scho Uplift (9)

Scho Uplift, west of Fish Creek Fault and northeast of Rat Uplift, embraces almost the same lower and upper Paleozoic and Jurassic stratigraphic successions as Rat Uplift. The exception is the Upper Devonian Imperial Formation which was removed during the Ellesmerian event so that unnamed Permian clastics rest with

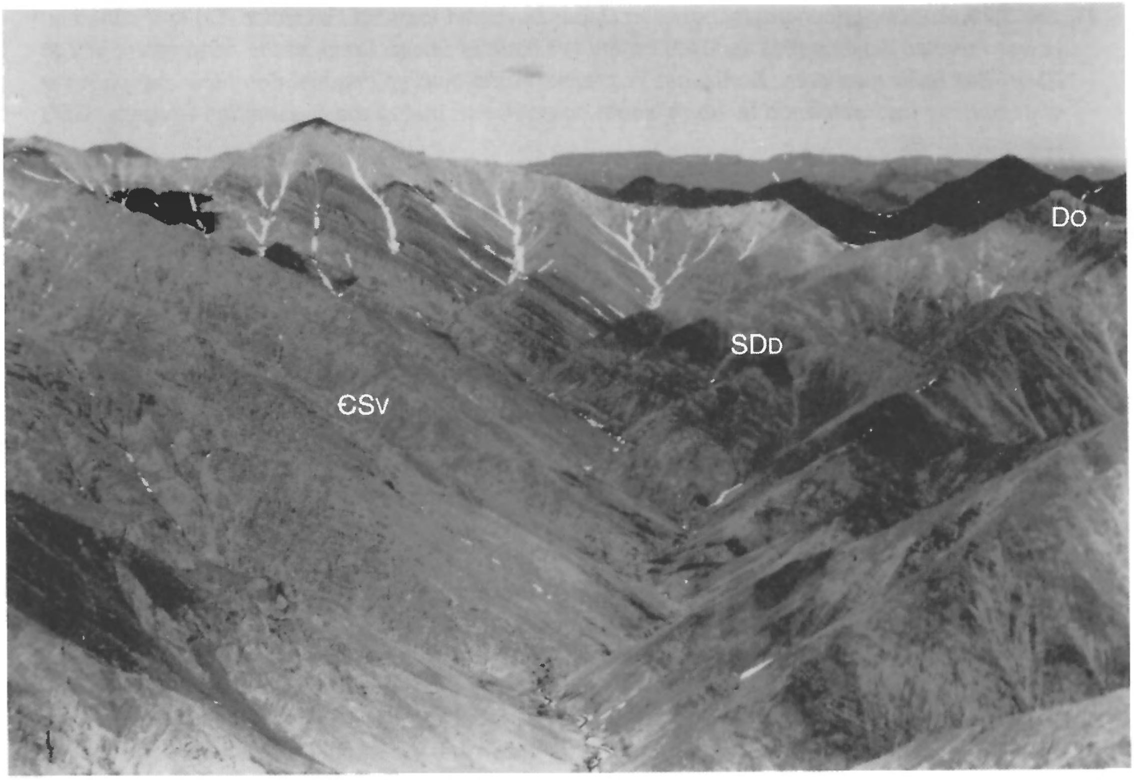

Figure 3.22. *East-dipping, middle and lower Paleozoic carbonate rocks comprising the core of White Uplift at the headwaters of Fish Creek, Bell River map area, Yukon Territory. Resistant, light grey weathering Vunta Formation* (ЄSv) *is overlain disconformably by pale orange and grey weathering, Upper Silurian and Lower Devonian Delorme Formation* (SDd), *capped with castellated Lower and Middle Devonian Ogilvie Formation* (Do). *ISPG photo 1860–6, looking north (Norris, 1981c).*

Figure 3.23. *Angular unconformity between Upper Devonian Imperial Formation* (DI) *and unnamed Lower Permian clastics* (Pu) *exposed on the left bank of Sheep Creek at the headwaters of Rat River, Bell River map area, Northwest Territories. North-dipping Imperial Formation beneath the unconformity was deformed by north–south compression during the Ellesmerian Orogeny. GSC photo 1173–85.*

angular unconformity on lower Paleozoic Road River Formation (Norris, 1981c, d). Moreover, right-hand separation of Rat Uplift, with respect to Scho, across Fish Creek Fault would suggest that the two uplifts were offset by right-lateral reactivation of the fault during the Columbian(?) orogeny.

Eskimo Lakes Block (13)

Eskimo Lakes Block is a northeast-trending subelement of the Aklavik Arch Complex. It is flanked on the northwest by the Eskimo Lakes Fault Zone and on the southeast by the northern Interior Platform. It surrounds Campbell Uplift on three sides. The block is a gently northwest-dipping panel of Phanerozoic rocks resting unconformably upon a thick succession of Inuvikian and Werneckian sequences (Norris, 1983a). The whole has been systematically depressed toward Canada Basin on a family of listric extension faults out to and including the Eskimo Lakes Fault Zone (Cook et al., 1987).

Campbell Uplift (12)

Campbell Uplift (Chapter 13) is the easternmost surface expression of the Aklavik Arch Complex. It occurs on the east side of the Mackenzie Delta adjacent to the northern Interior Platform (Fig. 3.1). Proterozoic (Inuvikian) dolomite, shale and sandstone are exposed in its core (Fig. 3.3) and lower and middle Paleozoic carbonates on its flanks (Dyke, 1975; Norris, 1981e; Chapter 13). The contact between the two successions has not been observed. It is considered, however, to be angularly unconformable because Proterozoic strata have dips up to 55° whereas overlying Paleozoic formations are only gently folded (Dyke, 1975). A family of northeast-trending, curviplanar, steeply dipping extension faults cuts the Paleozoic succession on the southeast flank of the uplift and depresses it in the direction of the platform. Sitidgi Graben (Fig. 3.25) occurs on its southeast flank. The uplift plunges northeast beneath Lower Cretaceous and younger rocks of the Tuktoyaktuk Peninsula. From boreholes, similar trends in the subsurface can be

Figure 3.24. Isoclinal folds in rhythmically interbedded shale and siltstone of the Imperial Formation on the right bank of Sheep Creek, at the headwaters of Rat River, Bell River map area, Northwest Territories. Note the requirement for detachment surfaces within the layered succession in order that the folds could collapse. The deformation was in response to north–south compression during the Ellesmerian Orogeny. ISPG photo 662–123.

traced northeast (Wielens, 1987), obliquely across the peninsula to the continental shelf.

Crustal seismic reflection data (Cook et al., 1987) outline the broad anticlinal form of the uplift in cross-section at the structural level of the Paleozoic carbonates. They also indicate the presence of about 15 km of layered Proterozoic rocks beneath the uplift, resting on basement of uncertain type and origin. The reflection geometry of the Proterozoic succession is strongly suggestive of the presence of both north- and south-verging contraction faults. It suggests they strike parallel to the long direction of the uplift and thicken the sedimentary and volcanic(?) succession comprising it (op. cit.). The configuration of these compressional faults facing one another is not unlike that of the Laramide Triangle Zone (P.L. Gordy, Internal Report, Shell Canada Resources Ltd., 1977) at the interface between the Frontal Belt of the Columbian Orogen and the Interior Platform of southwestern Alberta. It could be the deformation front of a mid-Proterozoic thrust and fold belt in northwestern Canada (Cook, 1988) whose surface manifestations are noted along the length of the Aklavik Arch Complex from Campbell Uplift to the Keele Block.

It is apparent that the Aklavik Arch Complex is a tectonic association of uplifted and depressed subelements that were active independently and intermittently, beginning possibly in the mid-Proterozoic and continuing through to the mid-Tertiary. Trending obliquely to the regional structural grain of the Frontal Belt of the Columbian Orogen, it is demonstrably a highly mobile element that participated in at least four major orogenies affecting the northern Canadian Cordillera: beginning with the Racklan(?) in the mid- to late Proterozoic; the Ellesmerian at the end of the Devonian Period; the Columbian in the early Late Cretaceous; and the Laramide in the Late Cretaceous to mid-Tertiary (Table 3.1). Both structurally and stratigraphically it is one of the most complex elements in the eastern Canadian Cordillera and it has doubtlessly played a fundamental role in the evolution of the Cordilleran Orogenic System.

Romanzof Uplift (2)

Romanzof Uplift, defined by Payne (1955) in northeast Brooks Range, continues into Canada in the region of the British Mountains (Fig. 3.1). It was originally part of Colville Geanticline, uplifted in Tertiary time along east-striking reverse faults. The northern limit of the uplift in Canada may be a fault contact with Rapid Depression. Its southern interface with Old Crow–Babbage Depression is arbitrarily defined as the base of the Ellesmerian Sequence. The uplift plunges gently southeast beneath Ellesmerian and younger sequences at Trail River (Fig. 3.26).

The stratigraphic succession in the uplift is predominantly the Neruokpuk and Road River formations, with outliers of Franklinian and Ellesmerian rocks (Norris, 1981f, g). Shale, quartzite and limestone of the Rapitanian(?) Neruokpuk Formation are the core rocks in the central and southern parts of the uplift. They are in fault contact with shale, limestone and thin quartzite of the lower and middle Paleozoic Road River Formation on the north flank of the uplift. The depositional contact or unconformity between the two formations has not been identified. However, shale, quartzite and limestone of probable Early Cambrian age, found on the north flank of the uplift (Lane and Cecile, 1989), may be coeval with the lower part of the thick, unnamed, Lower and Upper Cambrian volcaniclastic, shale and limestone assemblage straddling the Yukon/Alaska border between Firth and Malcolm rivers (Norris, 1981f). Should this be the case, the contact between Road River equivalents and Proterozoic Neruokpuk may be unconformable (Norris, 1974, p. 33). Differences in dip and in intensity of deformation, as well as the occurrence of a variety of lithologic units of the Neruokpuk apparently in contact with the Cambrian volcaniclastics, support the thesis that the Neruokpuk was initially deformed prior to the Cambrian (Norris, 1974). They further document the proposal (Cook, 1988) of a Proterozoic thin-skinned thrust and fold belt in the region and observed in the Aklavik Arch Complex, Taiga-Nahoni Foldbelt and Richardson Anticlinorium.

On the crest and north flank of Romanzof Uplift, the Neruokpuk(?) and Road River formations are overlain with strong angular discordance by an Ellesmerian Sequence consisting of clastics and carbonates of Endicott and Lisburne groups, and Sadlerochit, Shublik and Kingak formations (Norris, 1981f).

Down the plunge of Romanzof Uplift, immediately west of Trail River, the Sedgwick Granite (Fig. 3.27) is observed to have intruded the Neruokpuk-Road River assemblage (Norris, 1981g). It has a radiometric age of 355 Ma (Wanless et al., 1965), and, it is the only known acid igneous intrusion breached by the Holocene erosion surface in the uplift. A regional

Figure 3.25. *Sitidgi Graben outlined by fault line scarps of resistant Lower and Middle Devonian limestone of the Gossage Formation on both sides of Campbell Lake (background), Aklavik map area, Northwest Territories. Dempster Highway is in the middle ground. The graben trends northeast, on the southeast flank of Campbell Uplift. It probably developed during the waning stages of the Laramide Orogeny through differential subsidence of the depressed block beneath the lake. ISPG photo 2049-47, looking northwest.*

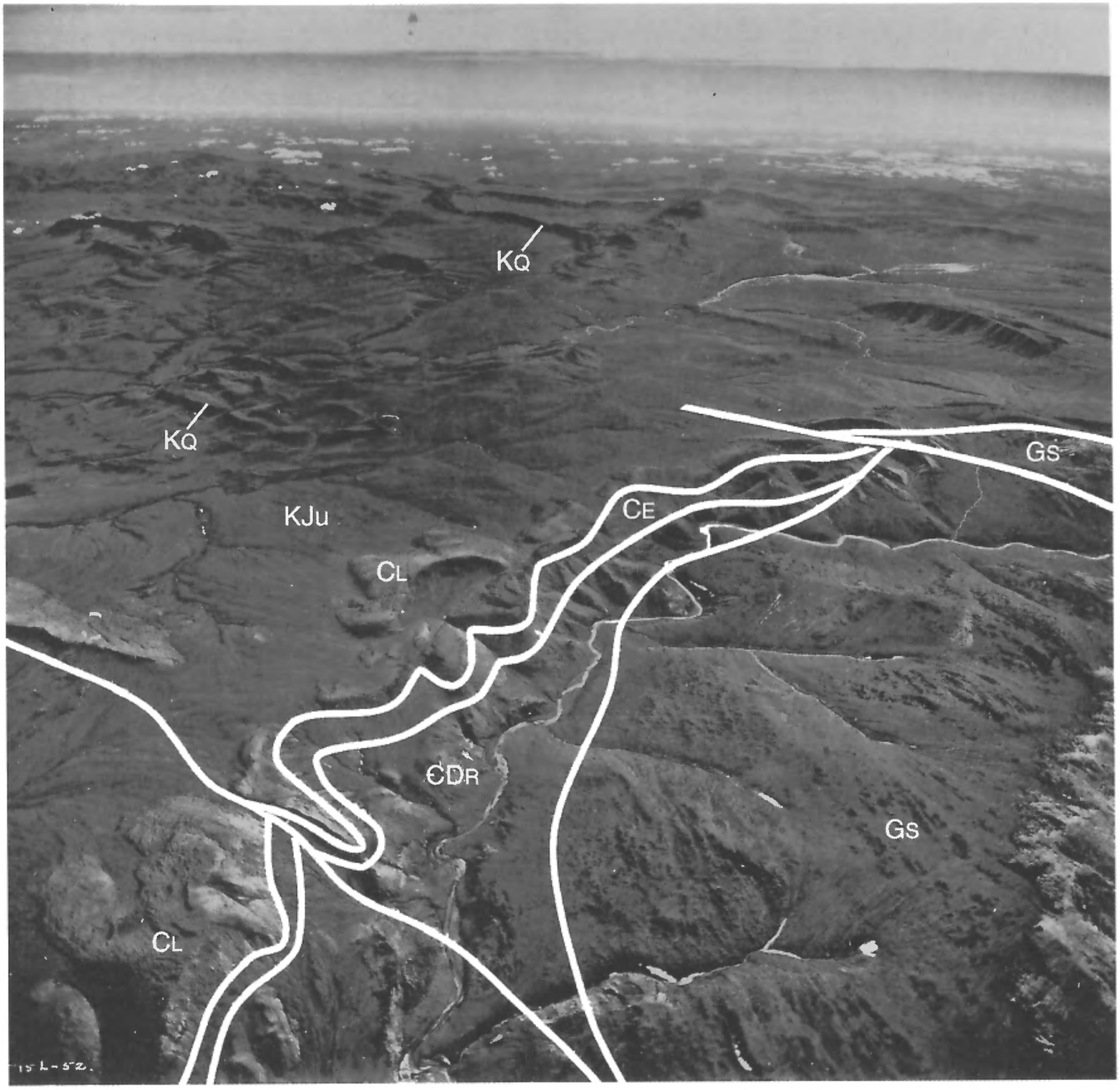

Figure 3.26. *Lower and middle Paleozoic Road River Formation(?)* (ЄDR) *and Sedgwick Granite* (GS) *at the southeast extremity of Romanzof Uplift, Blow River and Davidson Mountains map area, Yukon Territory. They are overlain with angular unconformity by folded and faulted Lower Carboniferous Endicott* (CE) *and Lisburne* (CL) *groups, Shublik Formation (not identified) and undivided Jura-Cretaceous clastics* (KJu). *Resistant quartzites of the Lower Cretaceous Kamik Formation* (KQ) *outline Laramide folds in the background. NAPL oblique photo T15L–52, looking south.*

aeromagnetic survey of the northern Yukon and adjacent continental shelf (D.K. Norris, GSC Internal Report, 1986), moreover, revealed a strongly positive anomaly associated with the Sedgwick Stock. Anomalies of similar strength beneath Gravel and Joe creeks to the west would suggest the presence of granitic cupolas or other stocks at shallow depths within the uplift. Minor basic dykes and sills intrude what appear to be the oldest exposed rocks of the Neruokpuk.

At least four regional orogenic events are recorded within the stratigraphic succession. Evidence for the earliest event can be seen along the Yukon/Alaska border where the Rapitanian(?) Neruokpuk Formation is overlain unconformably by the unnamed volcaniclastics at the base of the Franklinian Sequence. Evidence for the next event is seen beneath the outliers of Ellesmerian rocks. The whole was contracted, extended and uplifted in the Columbian and Laramide orogenies.

Collectively, these events appear to have resulted in one style of deformation for all sequences comprising the uplift, but with two contrasting intensities. One is the relatively simple stacking of a few plates of

***Figure 3.27.** Light-weathering Mount Sedgwick Stock (355 Ma) hosted in Road River Formation(?) on Mount Sedgwick, northern Yukon Territory. View is northeast toward Trail River and Yukon Coastal Lowland in upper background. ISPG photo 3566-2.*

Neruokpuk Formation, and outliers of Ellesmerian rocks riding piggy-back upon them, on both north- and south-verging contraction faults from the crown of the uplift down its southwest flank (Norris, 1981f, g). The other is the isoclinal folding (Fig. 3.28; Norris, 1985c) and imbrication of the Road River (and presumably Neruokpuk) Formation on closely spaced, high-angle reverse faults (Fig. 3.29) verging both north and south (Norris, 1973; Lane and Cecile, 1989) on the northeast flank of the uplift.

Old Crow-Babbage Depression (3)

Old Crow-Babbage Depression lies on the north flank of Brooks Range Geanticline as defined by Payne (1955). It is flanked on the north by Romanzof Uplift, on the east by Rapid Depression and Barn Uplift, and on the south by the Aklavik Arch Complex (Fig. 3.1). It is both a structural and physiographic depression surrounded by tectonic elements that were relatively uplifted during the Laramide Orogeny.

Sedimentary rocks ranging from the Proterozoic(?) to Lower Cretaceous occupy the depression. The oldest rocks are dolomite, shale and quartzite with mafic dykes and sills, exposed in the canyon of Porcupine River in the vicinity of the international boundary (Norris, 1981h). No fossils have been reported from them so they may be as old as Proterozoic (Helikian?; Table 4.1). They are in fault contact with fossiliferous Middle Jurassic shale of the Kingak Formation (Norris, 1981h). On the north flank of the depression, the pre-Kingak Ellesmerian Sequence is fully developed, with a thick succession of Endicott and Lisburne groups, and Sadlerochit, Shublik and Kingak formations capped with Lower Cretaceous Kamik quartzite.

Two granitic intrusions have been identified within the depression in Canada: one on Ammerman Mountain, straddling the international boundary with Alaska, between Firth and Crow rivers; and the other in Old Crow Range (Old Crow Batholith), also straddling the boundary, on the south flank of the depression. The Mount Schaeffer Stock, immediately east of Old Crow River, is probably continuous at depth with the Old Crow Batholith. Radiometric ages as old as 356 Ma have been reported for these bodies (Norris and Yorath, 1981), suggesting acid intrusive activity in earliest Carboniferous time, coincident with the migration of the Ellesmerian deformation front southward through the region.

Old Crow–Babbage Depression appears to be a complex association of structural highs and lows, about one-half buried beneath Tertiary and Quaternary nonmarine deposits on Old Crow Plain (Norris, 1981h). Acutely folded and faulted Ellesmerian clastics and carbonates wrap around the north and east flanks of the depression. Moreover, gently northeast-dipping Endicott Group exposed in the middle of the plain suggests the presence of uplifted fault blocks that continue northwestward beneath the Quaternary lake deposits to connect with Endicott and younger formations exposed in the upper reaches of Firth River (Norris, 1981g). If these hydrocarbon source and reservoir rocks are folded and sealed beneath the plain, their potential for oil and gas is worthy of consideration.

The southeast-trending contraction faults on the north flank of the depression are components of the Brooks Range Thrust Belt in Alaska. They repeat the upper Paleozoic succession and appear to have glided in a major detachment in shale and coal of the Endicott Group. In eastern Brooks Range and in British Mountains, the number of thrust faults comprising the belt, their stratigraphic separations, and the net crustal shortening incurred on them are

Figure 3.28. *Isoclinal folding in rusty weathering, slaty argillite of lower and middle Paleozoic Road River Formation(?) on the northeast flank of Romanzof Uplift. Exposure is on the left bank of lower Firth River, Herschel Island and Demarcation Point map area, Yukon Territory. ISPG photo 3–1–71, looking northwest (Norris, 1985c).*

observed to decrease progressively southeastward so that on the west flank of Barn Mountains only a few, discontinuous faults remain (Fig. 3.30). They commonly can be mapped for a few tens of kilometres. Rarely do they possess the great lateral extent that characterizes them in Alaska and in the Frontal Belt of the Columbian Orogen of southern Canada.

Barn Uplift (4)

Barn Uplift (Chapter 13) lies along the interface between Old Crow–Babbage and Rapid depressions (Fig. 3.1). It is defined (Norris and Yorath, 1981) as the northerly elongate area of exposure of highly compressed lower Paleozoic strata coeval with the Road River Formation in Richardson Mountains. The stratigraphic succession comprising the uplift, according to Dyke (1974), is an assemblage of dark grey to black, red and green shales, black and green chert, ridge-forming grey quartzite and argillaceous siltstone (commonly with load casts) and light grey limestone. The lithologies of this unnamed succession contrast markedly with the black, silty shale and limestone of the type Road River Formation in Richardson Trough. They are, however, similar to the slaty, grey, black and red argillite, grey quartzite and grey limestone on the north flank of Romanzof Uplift that

Figure 3.29. *Northeast flank of Romanzof Uplift (British Mountains) in the vicinity of Spring River, Herschel Island and Demarcation Point map area, Yukon Territory. Lower and middle Paleozoic Road River Formation(?) is acutely folded and faulted (Lane and Cecile, 1989), with southwest dips prevailing. NAPL oblique photo T13L–42, looking southeast toward Sedgwick Granite* (Gs).

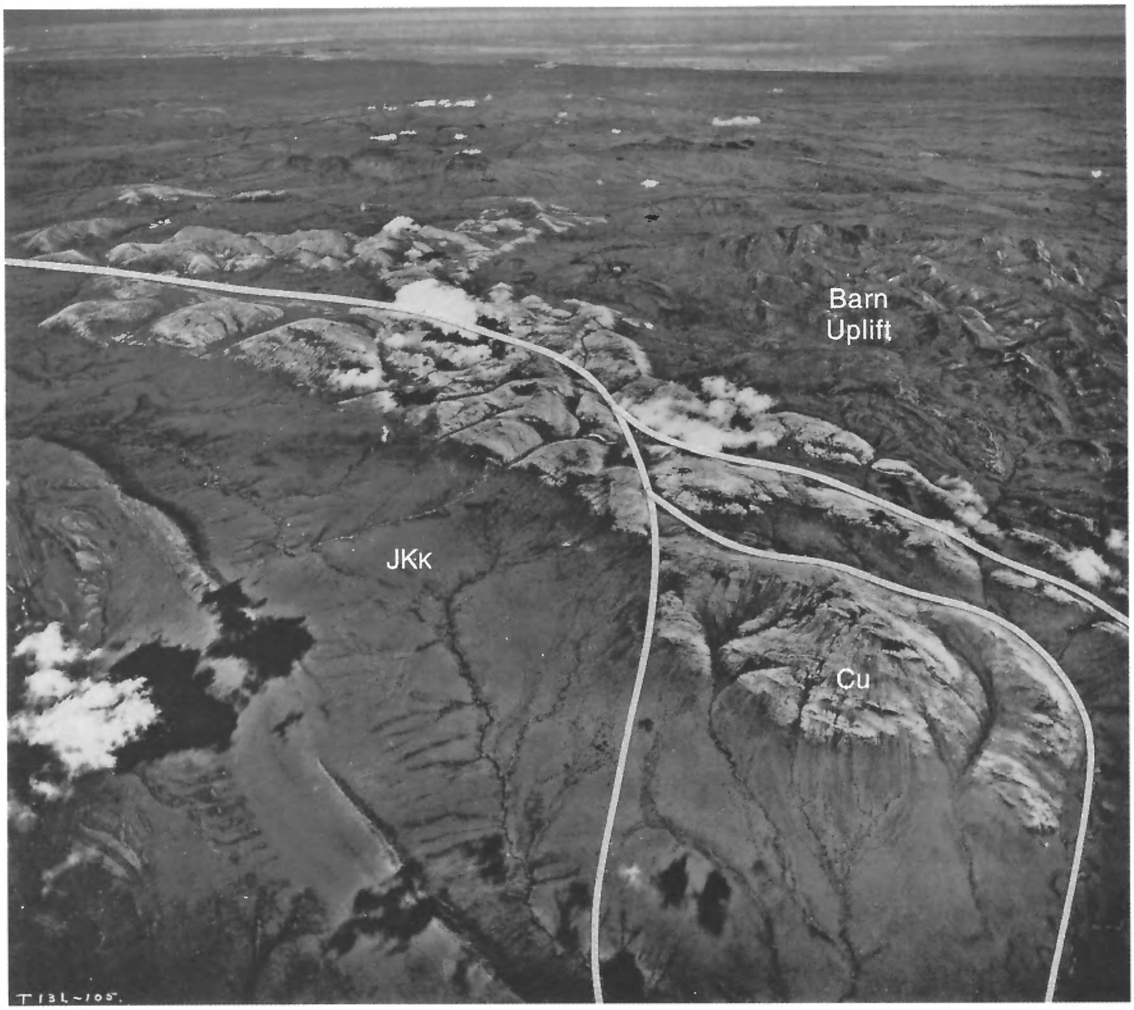

Figure 3.30. *West flank of Barn Uplift, Blow River and Davidson mountains map area, Yukon Territory. Undifferentiated Upper Paleozoic Endicott and Lisburne groups* (Cu) *and Kingak Formation* (JKĸ) *are repeated on east-verging contraction faults at the southeast termination of Brooks Range Thrust Belt. NAPL oblique photo T13L–105, looking north.*

are assigned to the lower Paleozoic Road River Formation (D.K. Norris, this volume, p. 49). They are overlain with angular unconformity by the Kekiktuk Formation at the base of the Ellesmerian Sequence. Granitoid rocks of Hoidahl Cupola in the northern part of the uplift are dated as old as 406 Ma (Bell, 1973), suggesting they were intruded in earliest Devonian time, some 40 Ma prior to the Ellesmerian Orogeny.

Barn Uplift is divided into a number of elongate blocks bounded by subvertical, north-trending, curviplanar, listric, generally eastward-verging contraction faults active in the Ellesmerian Orogeny. Moreover, repetition of graptolite faunules in adjacent blocks indicates that the rock succession from east to west across the uplift is a series of highly folded, generally steep-dipping panels (Chapter 13). Detailed mapping by Cecile (1988) supports this premise. Minor reactivation of some of the faults in the Columbian or Laramide orogenies resulted in overlap or repetition of the Ellesmerian cover rocks.

Of particular tectonic interest is the change in strike of these lower Paleozoic beds and their cover rocks from the southeast in Romanzof Uplift to the south in Barn Uplift. The change is believed to have been initiated through the bending of part of the Cordilleran Orogenic System about an axis located at the headwaters of Blow River (Norris, 1983b, 1987). This bending is part of the regional, southward curvature in the Alaskan Orogen, identified as the Brooks Orocline, and appears to be one of the few true oroclines in the Cordilleran Orogenic System. It is postulated that bending increased in the early Tertiary as the Arctic Alaska Plate was translated eastward and dragged along the Kaltag Fault.

Beaufort-Mackenzie Basin (21)

Beaufort-Mackenzie Basin (Fig. 3.1) is a Laramide exogeocline on the northern mainland and continental shelf. It is a contractional successor basin overlapping Rapid Depression and the Aklavik Arch Complex. It is roughly triangular in plan, with its apex pointing southward into the upper reaches of Blow River, and with its base coinciding with the outer edge of the shelf. Its sides are drawn at the erosional edge of the Laramidian Moose Channel Formation so that the entire Paleogene section, including the hydrocarbon-bearing lower Tertiary, is embraced within it. This definition differs from that of Dixon et al. (1992) in that it excludes the Maastrichtian Tent Island Formation.

Rapid Depression (1)

Rapid Depression is a northeast-trending, structurally controlled trough between Old Crow-Babbage Depression and Romanzof and Barn uplifts on the west, and Aklavik Arch Complex on the east. On the continental shelf it is identified by the -40 and -50 mgal free air gravity anomalies in Mackenzie Bay (Seeman et al., 1989). The depression is V-shaped in plan, opening northward, and terminating up-plunge at the headwaters of Blow River.

The rocks filling much of the depression are turbiditic sandstone and conglomerate comprising the Lower Cretaceous part of the Columbian Sequence. More than 3000 m of these flyschoid rocks were deposited axially in the depression (Norris and Yorath, 1981). On the flanks, they are observed to thin markedly and to rest unconformably upon a variety of Ellesmerian units. More than 1200 m of Upper Cretaceous and Tertiary Columbian and Laramidian clastics were deposited on top of the flysch in the depression.

The general eastward-fining trend, paralleling downcurrent paleodispersal directions in the flyschoid sequence (Young, 1973), and the marked contrast in mineralogical maturity between the Ellesmerian epicontinental and Columbian flyschoid phases support the concept of a redistribution of provenances and depositional sites in the Albian. During the Jurassic and earliest Cretaceous, the widespread epicontinental, marine, mineralogically mature sandstone and shale succession was derived from the craton to the east and southeast. In the late Early Cretaceous, texturally and mineralogically immature chert, lithic sandstone and conglomerate began to be shed from the deforming and uplifting regions deeper into the orogen to the west and southwest. This change from the Ellesmerian to the Columbian Sequence in the mid-Early Cretaceous marks the initiation of the Columbian Orogeny in the Frontal Belt of the Columbian Orogen.

The nature and timing of the structural events controlling Rapid Depression are revealed by the family of nearly vertical, strike-slip? and contraction faults (Rapid Fault Array; Fig. 3.6) and folds within and bounding the depression (Norris, 1981g). On its west flank Barn Fault isolates Barn Uplift from the depression. Across it the granitoid rocks of Hoidahl Cupola are separated 10 km right-laterally from the granites of Mount Fitton. Northward from Barn Mountains, the fault swings to the west and changes to a curviplanar, south-dipping thrust fault. Contractional displacement on the thrust would require right-hand slip where the fault trends south between Barn Uplift and Rapid Depression, thereby accounting for the sense of offset of the granite intrusions from one another and setting an upper limit to the horizontal component of displacement.

Gilbert Fault is on the east flank of the depression (Norris, 1981g). Along it, folded and broken Lower Cretaceous Rat River and older formations are uplifted, truncated and juxtaposed against Albian rocks filling the depression. The sense of displacement on it is uncertain, beyond the obvious vertical separation allowing for relative down-dropping of the depression to the west. The right-hand en echelon array of folds (including Gilbert Anticline; Fig. 3.18) adjacent to it within the Aklavik Arch Complex, however, strongly suggests that there had been right-hand offset on Gilbert Fault as well.

Buckland Fault (Norris, 1981g) within the depression is a near-vertical, planar feature traceable 65 km from the headwaters of Bell River northward to Yukon Coastal Lowland. There, it is buried beneath marine, terrace gravel. Along its length, its east and west walls are alternately uplifted and depressed, suggesting that it is a strike-slip fault also. Moreover, the Lower Cretaceous Kamik Formation is separated 13 km right-laterally across it near its southern mappable limit at the headwaters of Bell River.

Yukon (Skull) Fault, one of the most fundamental structural features of the lithosphere in this northern part of the Frontal Belt, is medially within Rapid Depression (Norris, 1981g). From the Tintina Fault it is traceable about 480 km to the Yukon Coastal Lowland. Within the depression it appears to be a near-vertical, curviplanar fault with reciprocation of relatively uplifted and depressed walls. Fifteen kilometres east of Bonnet Lake, resistant quartzites and siltstones of Jurassic and Early Cretaceous age are uplifted against the Lower Cretaceous Mount Goodenough Formation to form one of the most spectacular fault-line scarps in the northern Cordillera. At the headwaters of Driftwood River, the fault is graphically displayed with outcrops of highly fractured and faulted slices of Road River(?) cherty dolomite strung out along it for a distance of 9 km (Fig. 3.31). Immediately west of there, a horse of resistant quartzite of the Lower Cretaceous Martin Creek Formation is caught between splays from Yukon (Skull) Fault. Bedding within it strikes east, rather than north, parallel to the regional structural grain (Fig. 3.31, GSC loc. C-138097). It may have been rotated and translated because of drag in the fault zone. A more likely scenario, however, is that it is part of a syncline in the Martin Creek Formation 5 km along strike to the south and that it has been separated left-laterally from the syncline because of differential uplift in the fault zone in mid-Cretaceous or later times.

Kaltag Fault passes mid-way between Yukon (Skull) Fault and Hoidahl Dome to be lost beneath the gravel covering of Yukon Coastal Lowland. Crossing Porcupine River 14 km upstream from the village of Old Crow (Norris, 1976), the fault strikes northeast across the corner of Old Crow Plain. There, it is intruded by two or more resistant diabase dykes (Norris, 1981h) that are highly sheared by pre-Jurassic (Chapter 9) displacement on the fault. Its surface trace turns north through Blow Pass in the form of a giant "S", continuing across Yukon Coastal Lowland to the continental shelf of southern Beaufort Sea. There it appears to turn once more to strike northeast, following a prominent low in the magnetic basement (D.K. Norris, G.S.C. Internal Report, 1986) and appearing to coincide with a change in seismic reflection character (Dietrich et al., 1989) of the crystalline(?) crust north of Tuktoyaktuk Peninsula. According to Dietrich et al. (op. cit., p. 8) one possible geological interpretation of this change in character of the basement is a "fault separating two crustal blocks of different structural or lithological character". Could this be the Kaltag Fault? Norris (1972b, p. 98) first suggested the Kaltag Fault in this location and orientation beneath the continental shelf, that it may be the northwestern limit of the ancestral North American Plate, and that the parts of Alaska and Yukon Territory north of it may be a piece of the Eurasian Plate. The seismic investigations of Dietrich et al. would tend to support these suggestions.

The megascopic structure of Rapid Depression, therefore, is a series of north-striking panels within Rapid Fault Array. Of secondary importance are folds such as Rapid Syncline and Buckland Anticline between Buckland and Yukon (Skull) faults, and Blow and Deep Creek synclines close to the western margin of the depression. All strike sub-parallel to the long direction of the blocks containing them, all are broken by later transverse faults, all are more or less symmetrical and all indicate regional east-west compression and shortening across the long axis of the depression in Late Cretaceous or later times. Of minor significance are east- and west-verging contraction faults paralleling the major folds whose flanks they cut (Norris, 1981g), in addition to parasitic, mesoscopic folds and contraction faults (Lane, 1988) observed in cutbanks of some of the major rivers and streams.

The deformational history of Rapid Depression was prolonged. As indicated by D.K. Norris (Chapter 9), the bulk of horizontal displacement on the Kaltag Fault, for example, must have taken place prior to deposition of the Jura-Cretaceous Kingak Formation. The Kaltag appears to be a precursor of the Rapid Fault Array. Its surface trace in younger rocks, therefore, appears to be due simply to Columbian or Laramide reactivation with vertical offsets predominating. Right-hand separation of a few kilometres on Barn and Buckland faults, moreover, would suggest minor dextral shear within and on the periphery of the depression. Clearly no major offsets of facies boundaries or of formations of Jurassic (Chapter 10) or younger age should be expected within Rapid Depression. The 5 km of left-lateral separation suggested across Yukon (Skull) Fault Zone may indicate occasional reversals in slip direction within Rapid Fault Array.

The time span of deformational events recorded in Cretaceous and Tertiary rocks in Rapid Depression was set by regional factors, such as the migration of the Columbian and Laramide deformation fronts through the project area. Initiation of the Columbian Orogeny in the northern Cordillera was signalled by the wholesale restructuring of provenances and depositional basins beginning in the mid-Early Cretaceous (Hauterivian) and is recorded in the radical compositional changes in the rocks filling the depression.

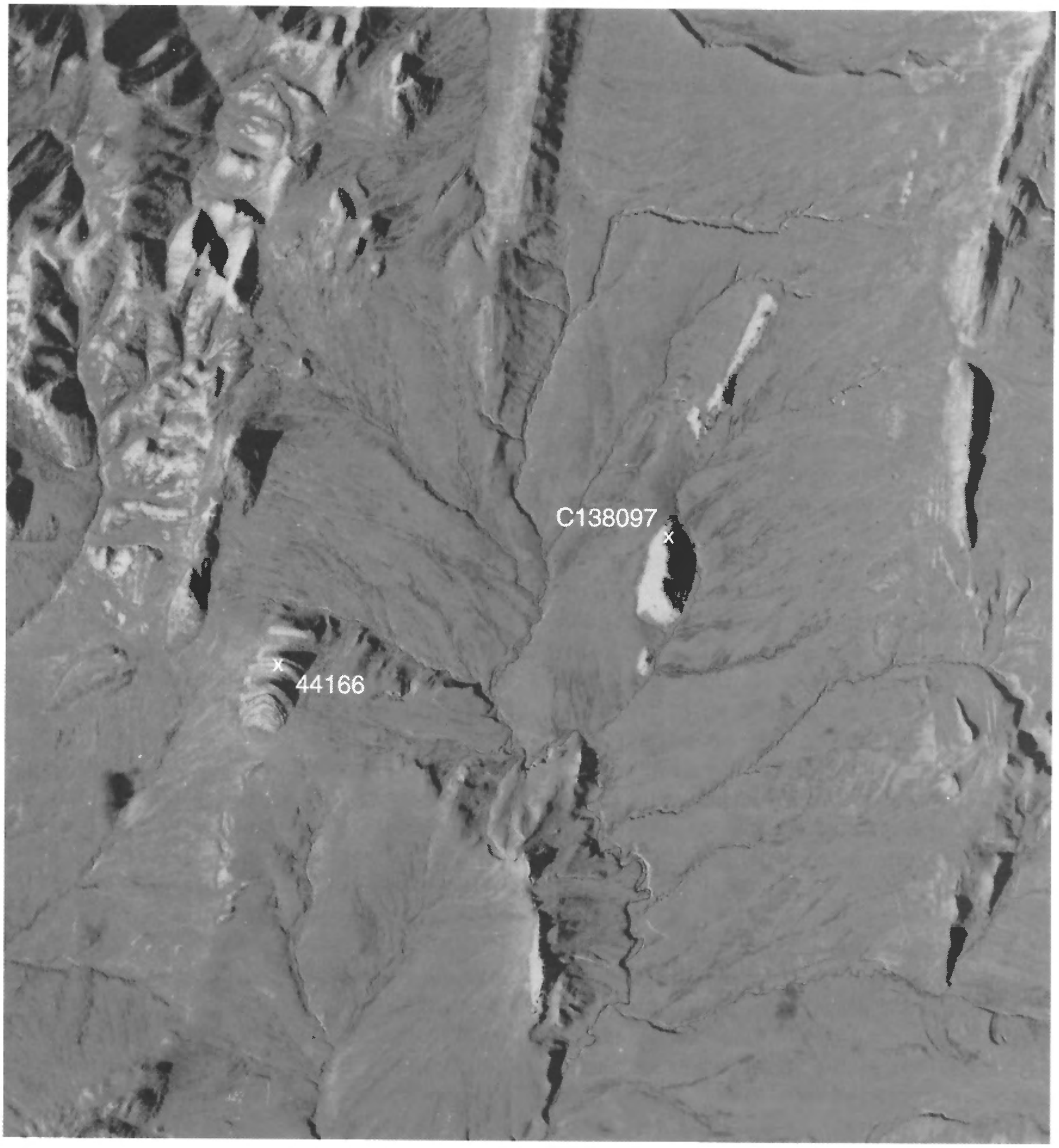

Figure 3.31. Resistant, white weathering, lower Paleozoic cherty dolostone (GSC loc. C–138097) and grey weathering Lower Cretaceous quartzite (GSC loc. 44166) forming horses in Yukon (Skull) fault zone of the Rapid Fault Array at the headwaters of Driftwood River. From NAPL photo A14451–8.

Evidence for the Laramide event, moreover, is best observed in the deformation of the early Tertiary Moose Channel and Reindeer formations on the outer fringes of Yukon Coastal Lowland. At the mouth of Big Fish River (Fig. 3.8), these relatively young rocks are in the form of a gently seaward-dipping homocline (Fig. 3.8) cut by northeast-striking, steeply dipping faults and locally rotated to vertical next to them (Norris, 1972b, p. 97, 1981g). At the opposite side of the depression in Deep Creek Syncline, they strike northwest, are gently folded, and are cut by a family of east-trending extension faults. The Laramide deformation on land in this northernmost segment of the Frontal Belt in Canada is, therefore, one of simplicity. Insofar as the acuity of the Laramide deformation can be expected to decrease in the direction of migration, that is in the direction of the continental shelf, it is surmised that the Laramide may have had little effect on the supracrustal wedge offshore beyond accentuation of the older diapiric folds and growth-faulted closures observed there (Norris, 1985b).

SEISMICITY
(D.A. Forsyth, R.J. Wetmiller and P.W. Basham)

Introduction

Earthquake records in the project area began with the establishment of seismic stations in the early 1960s. Information from earlier reports and limited data on the area's larger events since 1940, from distant stations, are presently under study at the Geological Survey of Canada. The south-central part of the area is one of the more seismically active areas in Canada. Thus data from the epicentre represent a very brief snapshot of earthquake activity. However the relationships already evident between regional geological features and concentrations or trends of seismic activity indicate that existing structures appear to be serving as the locus of stress release in present crustal dynamics. The available data do not permit resolution of the precise relationship between the crustal structures at depth and the seismic activity nor do they allow determination of the causative source of stress in the crust.

Seismicity Data Base

The historical development of the Canadian Arctic seismic network, which began in the 1960s and the earthquake data base for the Canadian Beaufort Sea are described by Leblanc and Wetmiller (1974), Forsyth et al. (1986), and Horner and Weichert (in press). To the west, Alaskan earthquake activity is described by Page et al. (1991), Grantz et al. (1983a, 1983b), and Fujita et al. (1990). The earthquake monitoring capability for the Yukon region was minimal prior to the extension of the national seismograph network to the north in the early 1960s (Stevens, 1974). Before this time, only the larger events were located, mainly on the basis of global seismograph records. These older events likely have large location uncertainties. Since the 1960s, the coverage has been complete down to about magnitude 3.5. Thus, the pre-1960 events on Figure 3.32 are distinguished by open symbols. In both of the major clusters of earthquakes, there are large pre-1960 events that are separated from the better located clusters, suggesting mislocations of up to 50 km for some of the older events. Since the earthquakes are evidence of local crustal rupture at depth, caution should be used in making correlations between individual epicentres and particular geological structures mapped only at the surface. However, the significance of the map (Fig. 3.32) is a very real spatial variation in contemporary seismic energy release throughout the region.

Relationship between seismicity and regional structural trends

Offshore

The epicentres near the northern limit of the area are part of a larger cluster of epicentres to the north which defines an active area in the eastern Beaufort Sea (Horner and Weichert, in press; Forsyth et al., 1990, Fig. 12; Hasegawa et al., 1979). The activity is bounded to the southeast by the Tarsiut-Amauligak Fault Zone (T-A) and Outer Hinge Line (Dixon and Dietrich, 1990). Most of the seismic activity occurs on structures within an active area defined by intersecting negative, linear magnetic anomalies. One shelf-parallel anomaly follows the T-A fault zone and the Outer Hinge Line while the intersecting low trends northwest and bisects the southern Beaufort Sea (Forsyth et al., in press). Present deep seismic data are insufficient to define the crustal structures that appear to outline the active area.

In contrast, the western Beaufort Sea north of Canada and much of the area along the continental shelf is essentially aseismic. Nearshore and onshore, low-level seismic activity coincides generally with the Eskimo Lakes Fault Zone (ELFZ). The area between the Eskimo Lakes Fault Zone and the Outer Hinge Line also appears aseismic.

Northeast of the study area, beneath the continental slope, Hasegawa et al. (1979) describe a nodal solution interpreted as indicating sinistral displacement along a fault plane with an azimuth of 45°, approximately parallel to the continental margin. The nodal plane solution also indicates that crustal stress in the area west of southern Banks Island is characterized generally by north-south compression and east-west tension. Nearshore to the southwest, long axes of measured well breakouts show a similar northeast-southwest compressive stress in the Mackenzie Delta area (Bell, 1987; Bell and Babcock, 1987). The relationships between tectonic elements and geophysical features in the delta area are described by Forsyth et al. (in press).

North of Alaska, an area of relatively concentrated seismicity off Barter Island coincides with structures beneath the continental margin. Grantz et al. (1983a) have shown that the earthquakes coincide spatially with an area where fault offsets in the seabed and

Pleistocene sediments are observed. Areas such as these, lying adjacent to active tectonic elements and covered by thick sections of unconsolidated sediments, may pose a special problem to resource utilization.

Details of the relationship between earthquakes and structural trends mapped from industry data are described in Estabrook (1988) and Grantz et al. (1983a, 1983b).

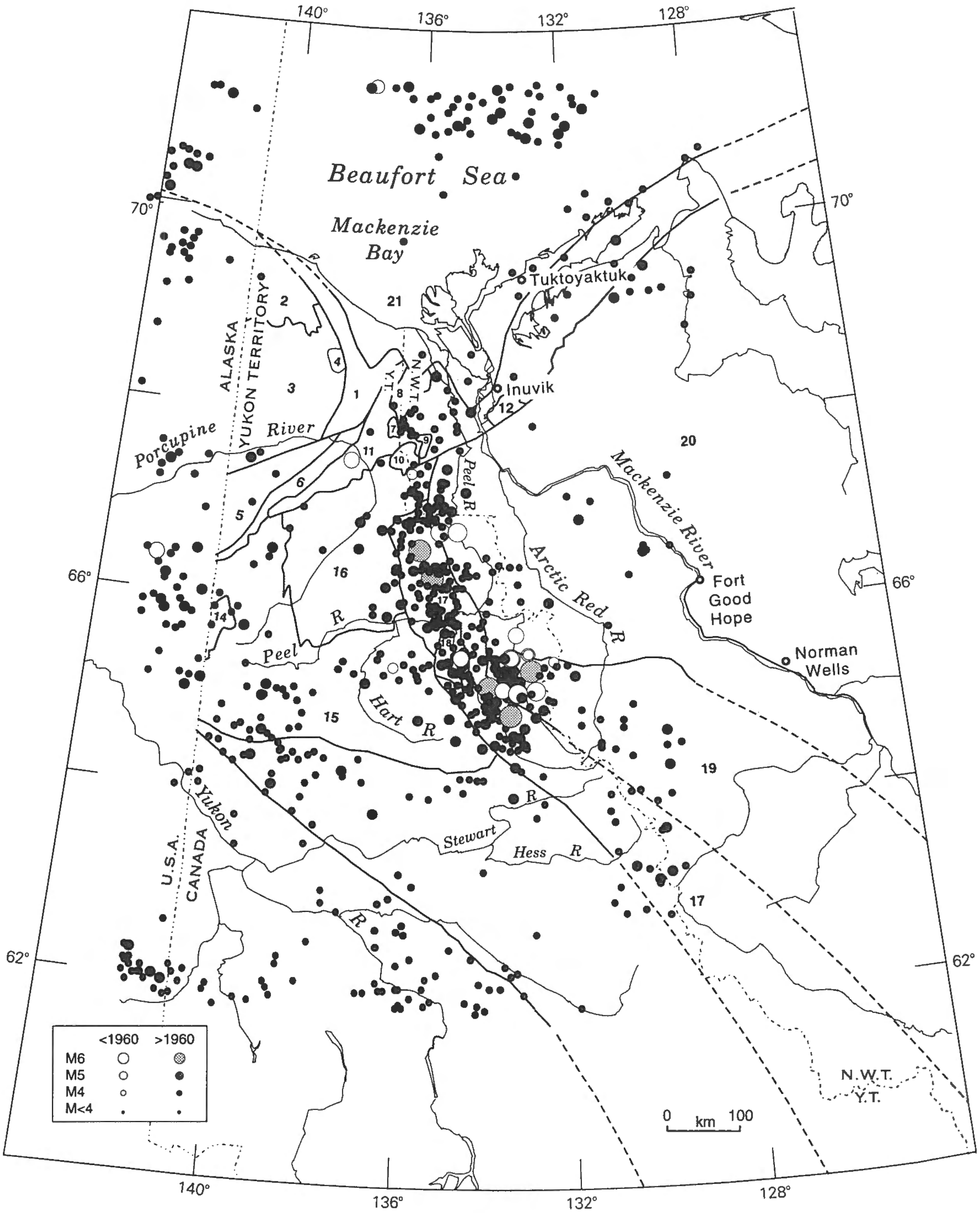

Figure 3.32. Seismicity in northwestern Canada and contiguous Alaska in relation to major tectonic elements of the northern Cordillera (Fig. 3.1), Interior Platform and adjacent continental shelf.

North

Except for scattered activity coincident with the eastern Eskimo Lakes Fault Zone, the northern coastal area represents a large inactive area. In particular, the British Mountains, Mackenzie Bay and northern Mackenzie Delta are all virtually aseismic in the recorded data.

Central

The central map area's main earthquake activity begins beneath the southern Mackenzie Delta and is concentrated along northwest and north-south trends parallel to structures of the Richardson Anticlinorium, but it also includes activity within the immediately adjacent terranes. The minor gap at 65°30′N coincides with the Bonnet Plume Basin area. The large cluster of events at the southern end of this trend coincides with the confluence of east-west and northerly trending structures from the Wernecke, Mackenzie and Richardson ranges (Fig. 3.13). The Mackenzie Platform to the east is marked by scattered activity including two events of magnitude 5 which suggest a weak trend southwest of the Mackenzie River. The relationships between regional structure, epicentres and earthquake source parameters for the area to the southwest are described in Wetmiller et al. (1988), Horner et al. (1990) and Rodgers and Horner (1991).

To the west of the Richardson Mountains, scattered but moderate level earthquakes occur across the Taiga-Nahoni and Eagle foldbelts to eastern Alaska.

Southwest

To the southwest, a prominent northwest trending zone of activity lies parallel to and mainly north of the Tintina Fault (Ti). Note that while the Tintina Fault near Alaska appears as a southern limit to this zone of stress release, to the southeast the structural splays, including the late Mesozoic Teslin Suture Zone (Te; Hansen et al., 1991), are characterized by lower level activity.

The Yukon Crystalline Terrane (Monger and Berg, 1987), bounded by the Tintina and Denali fault zones, is largely aseismic. Activity increases markedly at the Denali fault zone (DN) southwest of the project area (Fig. 3.32) as part of a much larger area of activity associated with the present Pacific-North America plate interactions (Horner, 1983; Rodgers and Horner, 1991).

SUMMARY

The project area is one of the more seismically active parts of Canada. The available epicentre data represent a brief snapshot of earthquake activity. The events are distributed in clusters and trends that can be correlated with regional tectonic elements. Few fault plate solutions and regional location capability forbid placing strong constraints on particular relationships between tectonic features and contemporary seismic sources. Local recording networks with higher resolution than those in place could provide clues to the depth, orientation and relative motion in the more active areas, and to the probable stress sources. Seismic reflection and refraction surveys could provide acoustic images and model estimates of the crustal structure at depth.

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CHAPTER 4

PROTEROZOIC

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Abstract

The Proterozoic rocks form a major component of the supracrustal wedge in northern Yukon Territory and western District of Mackenzie. They are composed mostly of sedimentary, clastic rocks of lower greenschist facies and rest with profound unconformity upon crystalline igneous and metamorphic rocks of the Hudsonian basement. The composite thickness of the Proterozoic succession is estimated to be between 30 and 35 km, of which about 25 km are exposed.

The Proterozoic succession ranges in age from 1735 to 600 Ma, about twice the time span of the Phanerozoic Eonothem. Four regional unconformities allow its subdivision into three basic tectonostratigraphic sequences, from oldest to youngest: Werneckian (1.7–1.2 Ga), Inuvikian (1.2–0.8 Ga), and Rapitanian (0.8–0.57 Ga). The sequences are homotaxial with the lower Helikian, upper Helikian and Hadrynian respectively. They are separated by major orogenic or epeirogenic events affecting the northern Cordillera and adjacent Interior Platform. The early record of collisional and extensional tectonics of this northwest corner of the ancestral North American plate is contained in these Proterozoic rocks.

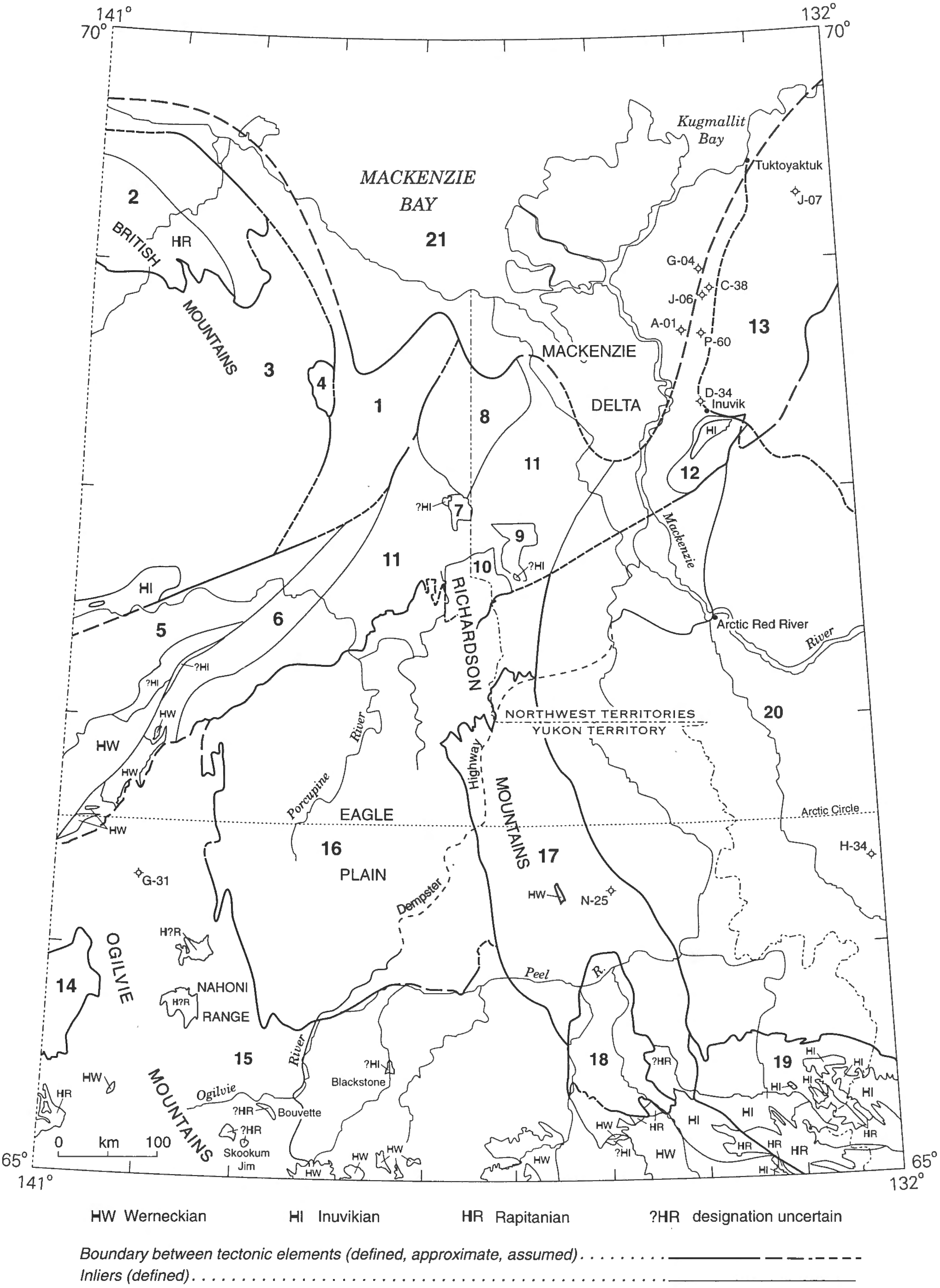
Résumé

Les roches protérozoïques forment une composante importante du biseau supracrustal du nord du Yukon et de l'ouest du district de Mackenzie. Elles sont surtout composées de roches clastiques sédimentaires du faciès des schistes verts inférieur et reposent en discordance profonde sur des roches ignées et métamorphiques cristallines du socle hudsonien. L'épaisseur composite de la succession protérozoïque est évaluée entre 30 et 35 km dont 25 km affleurent.

La succession protérozoïque varie en âge de 1 735 à 600 Ma, soit deux fois l'intervalle correspondant à l'éonothème phanérozoïque. Quatre discordances régionales permettent de la subdiviser en trois séquences tectonostratigraphiques de base, de la plus ancienne à la plus jeune : werneckienne (1,7 - 1,2 Ga), inuvikienne (1,2 - 0,8 Ga) et rapitanienne (0,8 - 0,57 Ga). Les séquences sont homotaxiques incluant respectivement l'Hélikien inférieur, l'Hélikien supérieur et l'Hadrynien. Elles sont séparées par des événements orogéniques ou épirogéniques majeurs qui ont modifié la Cordillère septentrionale et la Plate-forme de l'Intérieur adjacente. Les premières traces d'une tectonique par collision et extension dans ce coin nord-ouest de la plaque ancestrale de l'Amérique du Nord sont contenues dans ces roches protérozoïques.

INTRODUCTION

Proterozoic rocks underlie the entire project area, although they come to the surface in only about one half of the tectonic elements (Fig. 4.1). They are composed mostly of sedimentary rocks of remarkably low metamorphic grade considering the thermal and orogenic events to which they have been subjected. None is known to exceed lower greenschist facies. They lie with profound unconformity upon crystalline


141°
70°
132°
70°
65°
141°
65°
132°
MACKENZIE BAY
Kugmallit Bay
Tuktoyaktuk
J-07
G-04
C-38
J-06
A-01
P-60
D-34
Inuvik
MACKENZIE DELTA
BRITISH MOUNTAINS
RICHARDSON MOUNTAINS
EAGLE PLAIN
OGILVIE MOUNTAINS
NAHONI RANGE
NORTHWEST TERRITORIES
YUKON TERRITORY
Arctic Circle
Arctic Red River
River
Mackenzie
Porcupine River
Dempster Highway
Peel R.
Ogilvie River
Blackstone
Bouvette
Skookum Jim
G-31
H-34
N-25
1
2
3
4
5
6
7
8
9
10
11
11
12
13
14
15
16
17
18
19
20
21
HR
HI
?HI
?HI
?HI
?HI
HW
HW
HW
HW
H?R
H?R
HR
?HR
?HR
?HR
HI
HR
HW
?HI
0 km 100
HW Werneckian
HI Inuvikian
HR Rapitanian
?HR designation uncertain
Boundary between tectonic elements (defined, approximate, assumed)
Inliers (defined)

Tectonic elements

1 Rapid Depression
2 Romanzof Uplift
3 Old Crow-Babbage Depression
4 Barn Uplift
5-13 Aklavik Arch Complex
14 Kandik Basin
15 Taiga-Nahoni Fold Belt
16 Eagle Fold Belt
17 Richardson Anticlinorium
18 Bonnet Plume Basin
19 Mackenzie Fold Belt
20 northern Interior Platform
21 Beaufort-Mackenzie Basin

Figure 4.1. *Areal distribution of Proterozoic sequences in the tectonic elements of the northern Cordillera and Interior Platform. These sequences are: Werneckian* (HW), *Inuvikian* (HI), *Rapitanian* (HR), *designation uncertain (?). Heavy lines define element boundaries; light lines delineate inliers. Names of wells known or presumed to penetrate Precambrian rocks (e.g. H–34) are abbreviated from the text.*

igneous and metamorphic rocks comprising the westward continuation of the Canadian Shield beneath the northern Interior Platform and the Cordilleran Orogen.

The crystalline basement rocks were deformed in the Hudsonian Orogeny about 1735 Ma ago. None of them is exposed at the surface, although it is doubtless they were remobilized to form significant components of the lower and middle Paleozoic intrusive suite hosted within the relatively unmetamorphosed supracrustal wedge. Northward they extend beneath the continental shelf of southern Beaufort Sea where they undergo transition to oceanic crust (Dietrich et al., 1989). The shelf edge and continental rise opposite northern Yukon Territory and northwestern District of Mackenzie, therefore, are interpreted to be underlain by oceanic crust.

The following statement of the distribution, physical stratigraphy and correlation of Proterozoic rocks within the project area is the result of an analysis of 22 measured sections, supplemented by data from numerous outcrops examined with helicopter support, and from several deep boreholes and seismic surveys. The initial work was done by R.M. Procter in 1962. Between then and 1975, in conjunction with the completion of reconnaissance maps, major strides in our understanding of these rocks have been made, by measuring many new sections and remeasuring some of those examined in 1962. For example, we now know that the Proterozoic rocks under consideration span close to 1.1 Ga, about twice the time span of the Phanerozoic Eonothem. Moreover, the exposed thickness of a composite section of these rocks is about 25 km, somewhat more than the 20 km estimated for the Phanerozoic section. An additional 5 to 10 km of older Proterozoic rocks may be present between those exposed and the Hudsonian crystalline basement. Therefore, this statement of the Proterozoic section is necessarily preliminary in nature. It is intended to inform the reader of the rocks that are known to be there, to present possible correlations among them from inlier to inlier, to allow interpolations between inliers, and to facilitate extrapolation from the Cordilleran Orogen into the subsurface of the northern Interior Platform and of the continental shelf of southern Beaufort Sea. The sedimentology of many of these rocks awaits additional study.

Four regional unconformities allow the subdivision of the Proterozoic section into three basic sequences (Table 4.1). They are, from oldest to youngest: Werneckian (1.7–1.2 Ga), Inuvikian (1.2–0.8 Ga), and Rapitanian (0.8–0.57 Ga) (Young et al., 1979; Norris, 1983). The sequences are homotaxial with the lower Helikian, upper Helikian, and Hadrynian respectively. The unconformities identify major orogenic or epeirogenic events. The hiatus at the base of the supracrustal wedge, cited above, marks the Hudsonian (compressional) Orogeny (1.735 Ga). All of the section from the Wernecke Supergroup to the base of the wedge is assigned to the Werneckian; some of it is detected only in seismic reflection profiles. The Racklan (compressional) Orogeny[1] (1.2 Ga) occurred between deposition of the Wernecke and the overlying Mackenzie Mountains Supergroup or Pinguicula Group (Inuvikian Sequence). In turn, the Rapitan Group and conformably overlying Hay Creek Group (Twitya, Keele and Sheepbed formations), comprising the Rapitanian in the project area, are separated from the Inuvikian by the Hayhook (extensional) Orogeny[1] (Young et al., 1979). The unconformity at the base of the Cambrian System defines the termination of Hadrynian sedimentation. Immediately south of the project area, however, trace fossils of Early Cambrian age have been reported from uppermost strata of the Harper Group, previously considered to be entirely Hadrynian (Mustard et al., 1988, p. 200).

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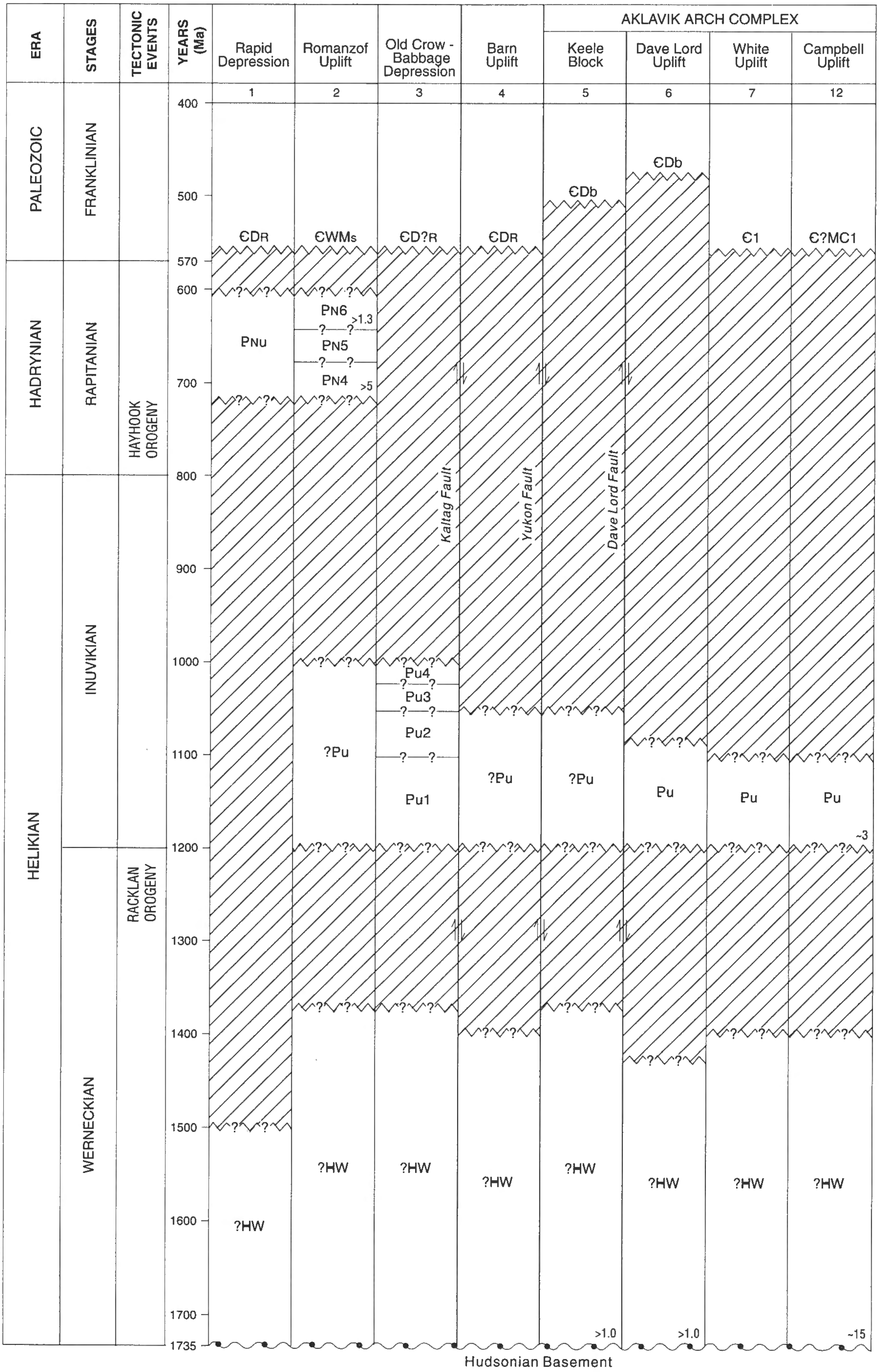
[1] The Geotectonic Correlation Chart (Norris, 1983), following Yeo et al. (1978), identifies the "Nadaleen Orogeny" as the (compressional) event defining the interface between the Werneckian and Inuvikian Sequences and, in turn, the "Racklan Orogeny" as the (extensional) event between the Inuvikian and Rapitanian Sequences. Current usage (Young et al., 1979), adopted herein, applies the term "Racklan Orogeny" to the older, compressional orogeny and the term "Hayhook Orogeny" to the younger, extensional event. The term "Nadaleen Orogeny" has been abandoned.


ERA
STAGES
TECTONIC EVENTS
YEARS (Ma)
AKLAVIK ARCH COMPLEX
Rapid Depression
Romanzof Uplift
Old Crow - Babbage Depression
Barn Uplift
Keele Block
Dave Lord Uplift
White Uplift
Campbell Uplift
1
2
3
4
5
6
7
12
PALEOZOIC
HADRYNIAN
HELIKIAN
FRANKLINIAN
RAPITANIAN
INUVIKIAN
WERNECKIAN
HAYHOOK OROGENY
RACKLAN OROGENY
400
500
570
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1735
ЄDR
ЄWMs
ЄD?R
ЄDR
ЄDb
ЄDb
Є1
Є?MC1
PNu
PN6
>1.3
PN5
PN4
>5
Pu4
Pu3
Pu2
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?Pu
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Pu
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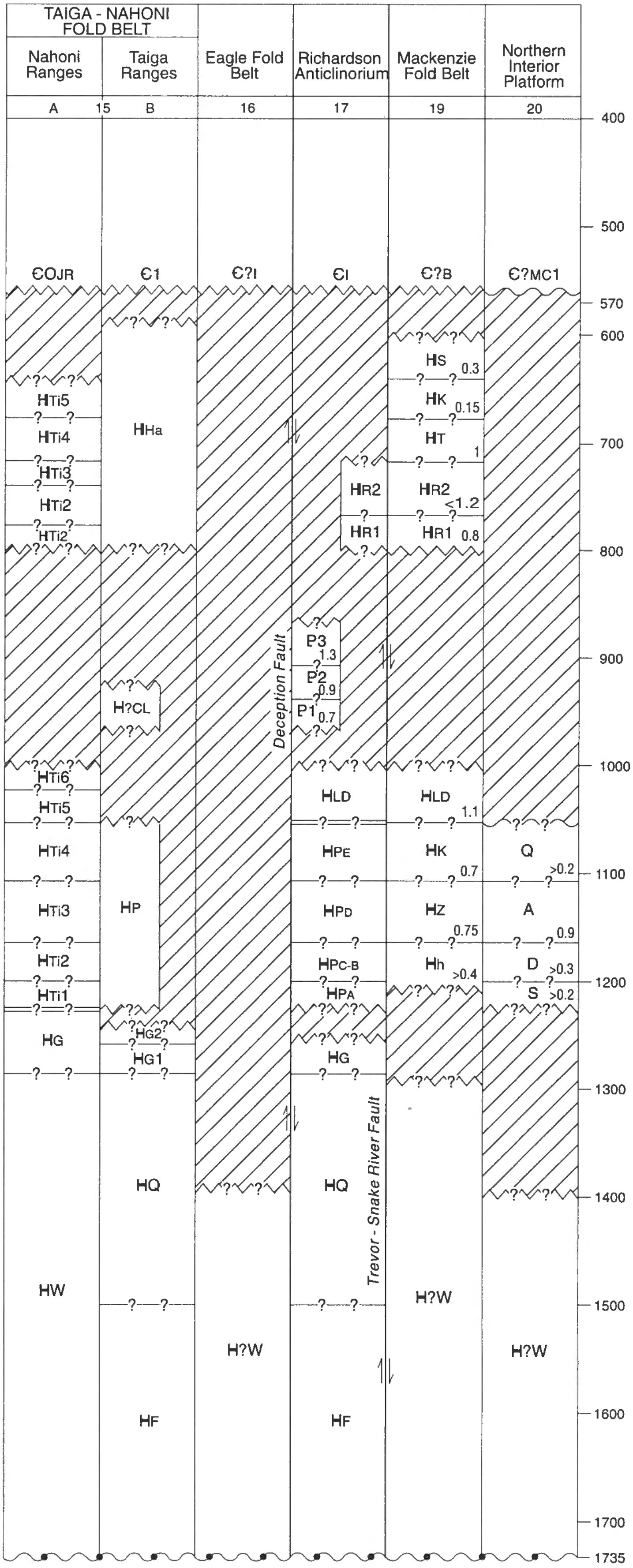
Pu
~3
Kaltag Fault
Yukon Fault
Dave Lord Fault
?HW
?HW
?HW
?HW
?HW
?HW
?HW
?HW
>1.0
>1.0
~15
Hudsonian Basement



Conformal contact, age presumed. . . . . —?—?—

Disconformity, defined. . . . . ∽∽∽

Angular unconformity, defined. . . . . ^^^^^^

Angular unconformity, age presumed. . . . . . . ^?^?^

Hudsonian nonconformity, defined. . . . . ∽•∽∽•∽

Major faults bounding tectonic elements;
arrows suggest presumed sense of slip . . . ⇌

Adjacent rock units not in contact;
age of interface presumed. . . . . ═?═?═

Stratigraphic interval undivided. . . . . Pu

Presence of stratigraphic interval presumed. . . . . ?Pu

Presence of specific rock unit presumed. . . . . H?W

Thickness of rock unit in kilometres. 1.3

Hiatus. . . . . ▨

Table 4.1

Schematic correlation diagram for middle and upper Proterozoic rock in the project area (parts of northern Yukon Territory and northwestern District of Mackenzie). Unit symbols are after Pugh (1983) and Norris (1985a). Stratigraphic columns are numbered according to their respective tectonic elements shown in Figure 4.1.

Table 4.2

Supplementary data for reference sections or type areas for middle and upper Proterozoic rocks in and adjacent to the project area

			Reference Section/Type Area						
Unit name	**Symbol(s)**	**Subunits**	**GSC no.**	**Longitude (west)**	**Latitude (north)**	**Geographic fix**	**Map area NTS/name**	**Thickness (km)**	**Reference(s)**
Neruokpuk Fm.	PN	PN4–6	117C1, 4	139°15′	69°05′	Wolf Ck., Y.T.	117 C	>6	Dyke, this chapter
Tindir Gp.	HTI HTI	"upper", 1–5 "lower", 1–6	— —	141°25′ 141°00′	65°01′ 65°15′ ±	Tatonduk R., Alaska Canada/Alaska boundary	Charley R. Charley R.	≤2.0 ≤2.0	Young, 1982 Brabb and Churkin, 1969; Cairnes, 1914, p. 5
Harper Gp.	HHA	—	—	—	—	Ogilvie Mts.	Dawson	≤1.8	Roots, 1987
Hay Creek Gp. Sheepbed Fm. Keele Fm. Twitya Fm.	 HS HK HT	 — — —	 — — —	 — — —	 — — —	 Backbone Ranges Backbone Ranges Backbone Ranges	 Snake R. Snake R. Snake R.	 0.3 0.2 ≤0.8	 Aitken et al., 1982 Aitken et al., 1982 Eisbacher, 1981; Young, 1982
Rapitan Gp.	HRU HRI	Shezal Sayunei	106F10 106F8	133°17′ 133°11′	65°15′ 65°14′	Snake R., Y.T. Snake R., Y.T.	Snake R. Snake R.	0-1.2 ~0.8	Green and Godwin, 1963, p. 15–18
unnamed	P3	—	106E10a	134°22′	65°28′	Knorr Rge., Y.T.	Wind R.	1.26	Dyke, this chapter
unnamed	P2	—	106E10a 106E2c	134°23′	65°23′	Knorr Rge., Y.T.	Wind R.	0.90	Dyke, this chapter
unnamed	P1	—	106E2b	134°20′	65°22′	Knorr Rge., Y.T.	Wind R.	0.71	Dyke, this chapter
Coates Lake Gp.?	HCL	—	116G13	139°44′	65°46′	Nahoni Rge., Y.T.	Miner R.	>0.1	Norris, unpublished
Little Dal Fm.	HLD	HLD2 HLD1	106F9 106F15	133°35′ 133°35′	65°20′ 65°18′	Backbone Ranges Backbone Ranges	Snake R. Snake R.	>0.75 >0.43	Procter, pers. comm., 1962 Dyke, this chapter
Katherine Gp.	HK	—	106F7	132°41′	65°28′	Canyon Ranges	Snake R.	>0.44	Procter, pers. comm., 1962
Tsezotene Fm.	HZ	—	—	—	—	Canyon Ranges	Snake R.	0.75	Aitken et al., 1982
unnamed	Hh	—	—	—	—	Canyon Ranges	Ramparts R.	>0.4	Aitken et al., 1982
Pinquicula Gp.	HP	HPA–E	—	133°20′	65°01′	Backbone Ranges	Snake R.	>1	Eisbacher, 1978, 1981
unnamed	Pu	— Pu1–4	107B3 116N3, 4	133°32′ 140°58′	68°18′ 67°25′	Inuvik airport Ramparts House	Aklavik Old Crow	~3 >1	Dyke, this chapter; Cook et al., 1987 Cairnes, 1914, p. 48
Wernecke Spg.	HWu	HG HQ HF	—	—	—	widespread	—	>13	Delaney, 1985
Gillespie Lake Gp.	HG	HG1–7	—	133°55′	64°45′	Wernecke Mts.	Nadaleen R.	~4	Delaney, 1985
Quartet Gp.	HQ	HQ1–2	—	134°00′	65°05′	Wernecke Mts.	Snake R.–Wind R.	~5	Delaney, 1985
Fairchild Lake Gp.	HF	HF1–5	—	133°40′	64°55′	Wernceke Mts.	Nadaleen R.	>4	Delaney, 1985

The Werneckian Sequence represents earliest Proterozoic sedimentation along the curvilinear northwest margin of the ancestral North American plate (Delaney, 1985). Therefore, it can be expected to underlie most if not all of the project area, although it is observed in outcrop only in Richardson Anticlinorium, Taiga Ranges and possibly in Aklavik Arch Complex (Fig. 4.1). Moreover, from shallow seismic reflection surveys (Cook, 1988; Cook et al. 1987), the sequence, or its equivalents, is inferred to be present beneath Colville Hills of the northern Interior Platform as well as beneath Campbell Uplift in the Aklavik Arch Complex.

The Inuvikian Sequence, also widespread in the project area, outcrops in Mackenzie Fold Belt, Richardson Anticlinorium, Taiga-Nahoni Fold Belt, Aklavik Arch Complex, and Old Crow–Babbage Depression. Homotaxial successions have been penetrated in the subsurface of the northern Interior Platform (see below).

The type area of Rapitanian rocks is in the southern Richardson Anticlinorium, east of Wind River, and in northwestern Mackenzie Fold Belt. Coeval formations of upper Tindir Group crop out in the hanging wall of Yukon Fault in the extreme southwest corner of the project area. The Neruokpuk Formation in Romanzof Uplift in the northwest corner of the area may also be Rapitanian. Volcanic and volcaniclastic rocks reported in the subsurface of the Aklavik Arch Complex beneath Mackenzie Delta (Wielens, 1987) may be correlatives of part of the upper Tindir and Rapitan groups (Table 4.1).

PHYSICAL STRATIGRAPHY AND CORRELATION

The following is a brief description of the rock units occurring within the project area. The units are listed in stratigraphic order in Table 4.2, along with relevant data on the location of the sections, ties to geological maps covering the area, and specific references. The units are discussed in approximate order, from oldest to youngest.

Fairchild Lake Group

(HF; *Table 4.1, Columns 15B and 17*)

The Fairchild Lake Group (Delaney, 1985) is at the base of the exposed Wernecke Supergroup. Its type area is in the Wernecke Mountains in the northwest corner of Nadaleen River map area, immediately adjacent to the project area. With an exposed thickness of about 4 km, it is made up of grey and greenish grey mudstone, siltstone and fine grained sandstone. Some carbonate members are important stratigraphic markers within the succession. According to Delaney (op. cit.) it is tentatively divided into five formations. The group has been recognized by Delaney along the southern boundary of the project area at the headwaters of Little Wind River. It may be exposed in the inlier transected by Blackstone River at the base of GSC Section 116G14 (Norris, 1982a) as well as in the Keele Range in southwestern Aklavik Arch Complex (Norris, 1981a).

Quartet Group

(HQ; *Table 4.1, Columns 15B and 17*)

The Quartet conformably overlies the Fairchild Lake Group. It is about 5 km thick and, according to Delaney (1985), it consists of dark grey weathering siltstone, fine grained sandstone, mudstone and claystone. The type area is in northern Wernecke Mountains in adjoining corners of Wind River (Norris, 1982b) and Snake River (Norris, 1982c) map areas, with superb exposures west of Quartet Lakes in the Wind River map area. Delaney (1985) has tentatively divided the group into two formations. The group is recognized, although undivided, in the Little Wind River and Blackstone River (Fig. 4.2) inliers, as well as in the Nahoni Range at the headwaters of Tatonduk River (Fig. 4.3; Norris, 1982a). It would appear also to be present in Keele Block (Fig. 4.4) and Dave Lord Uplift in the Aklavik Arch Complex (Fig. 4.1).

Figure 4.2. *Interbedded light grey quartzite and medium to dark grey, slaty shale of upper Quartet Group at GSC Section 116G14, immediately east of Blackstone River. ISPG photo 3590–8.*

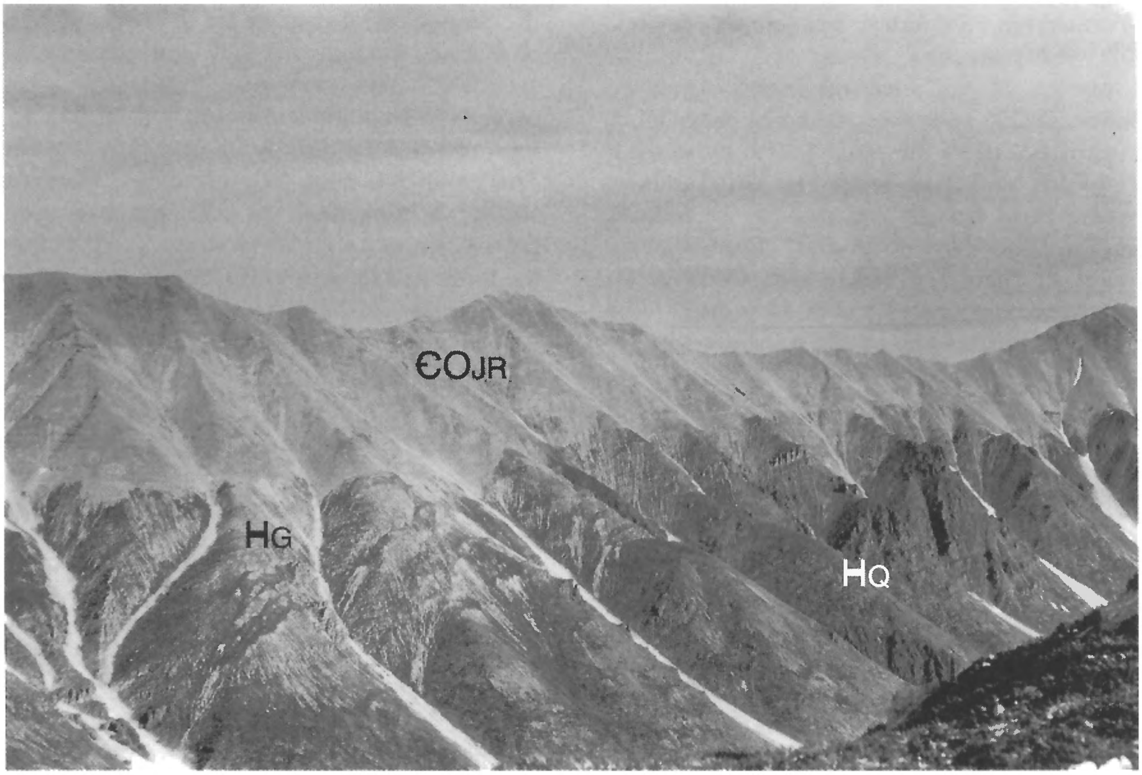


Figure 4.3. *Quartet Group (*HQ*) and Gillespie Lake Group (*HG*) overlain with angular unconformity by Cambro-Ordovician Jones Ridge Formation (*ЄOJR*) in the western Ogilvie Mountains; GSC Section 116F7 at the headwaters of Tatonduk River. ISPG photo 1860-27.*

Gillespie Lake Group (HG; *Table 4.1, Columns 15A, 15B, 17*)

The Gillespie Lake Group (Delaney, 1978) is in gradational contact with Quartet Group. It is about 4 km thick in the type area in northern Wernecke Mountains. According to Delaney (1985), the succession consists of resistant, pale orange and locally pale red weathering dolomite, silty dolomite and limestone, with mudstone, siltstone and fine grained sandstone toward the base. In the type area, in northwestern Nadaleen River map area, Delaney (1985) has tentatively divided the group into seven formations. Some, but not all, of them can be identified in the Wind River, Blackstone River (Fig. 4.5), Tatonduk River (Fig. 4.3) and Keele Range inliers.

Wernecke Supergroup undivided (HW)

As suggested above, Wernecke Supergroup is anticipated to underlie most, if not all, of the project area. In those tectonic elements where there are surface exposures of the supergroup, stratigraphic sections are commonly incomplete because of structure and cover rocks. In those elements where the supergroup does not come to the surface, it is not known if all three of the basic subdivisions of the supergroup are present. In these circumstances the supergroup is necessarily left undivided (Table 4.1). As far as it is known, it has not been drilled in the northern Interior Platform and northeastern Aklavik Arch Complex.

Wernecke Supergroup hosts numerous gabbroic, dioritic and lamprophyric dykes and sills as well as discordant breccia complexes of diverse ages. According to Delaney (1985), fragments of diorite occur in some of these breccia complexes, whereas similar dykes intrude other breccias and are hosted in rocks as young as Cambro-Ordovician (western Ogilvie Mountains). Delaney (op. cit.) reported K-Ar ages of 613 and 552 Ma in biotite from two samples of lamprophyre. In the western Ogilvies, however, some dykes must be younger than about 505 Ma, the Cambro-Ordovician boundary.

Most of these breccia complexes are developed on, or in close proximity to, various strands of the Richardson Fault Array. Delaney (op. cit.) notes that they are circular, elliptical or elongate in plan and range in width from a few metres to about 4 km. In

Figure 4.4. *Kink-folded slaty argillites and quartzites of presumed Wernecke Supergroup in the Keele Range southeast of Mount Rover. ISPG photo 3590-13.*

Figure 4.5. *Biostrome of columnar stromatolites in the Gillespie Lake Group at GSC Section 116G14, immediately east of Blackstone River. ISPG photo 3590-9.*

section they are subvertical. In the project area they are confined to the Wernecke Supergroup and hence appear to be older than about 1.2 Ga. In the Coates Lake area of central Mackenzie Mountains, however, one diatreme, apparently part of the Mountain Diatreme Suite, may be Ordovician (Jefferson and Parrish, 1989, p. 1794).

Mackenzie Mountains Supergroup (Table 4.1, Column 19)

This unit embraces a number of formations in northwestern Mackenzie Mountains (Fig. 4.1). These include the informal unit **H1** at the base of the section, overlain in turn by Tsezotene Formation, Katherine Group and Little Dal Formation. Within the project area, they are confined to the country east of Snake River Fault (Norris, 1982c).

Unit **H1** (**Hh**) is an unnamed formation consisting mostly of cherty, variably silty, pale grey weathering, finely crystalline to microcrystalline dolomite, that is mostly thick bedded and massive (Aitken et al., 1982). It is not known to be exposed within the project area but is anticipated to occur at depth in normal stratigraphic position beneath the Tsezotene Formation.

Tsezotene Formation (**Hz**) is concordant with underlying Unit **H1**, according to Aitken et al. (1982). Its contact with **H1** is not exposed within the project area. The formation consists of grey, greenish grey or brown shale with interbeds of very fine grained, thin to medium bedded, immature, grey and greenish grey sandstone or quartzite and orange weathering dolomite. It hosts many resistant gabbroic sills and dykes. This nondescript formation is not readily divisible into subunits and no sections have been measured.

Katherine Group (**Hk**) is in gradational contact with the underlying Tsezotene Formation and the contact is arbitrarily chosen for mapping purposes at some localities. The group consists mainly of mature, very fine grained, thin to very thick bedded, brown, greenish grey and white, orthoquartzitic sandstone with recessive intervals of dark grey to black shale. There are a few interbeds of orange and grey weathering, stromatolitic dolomite, especially in the upper part of the section. Katherine Group is confined to Mackenzie Foldbelt where it is extensively exposed in the cores of major folds and structurally uplifted fault blocks. It may include interlayered clastics and carbonates coeval with the so-called "Map unit **H5**" of Aitken et al. (1982) in Mackenzie Mountains immediately east of the project area.

Little Dal Group (**HLD**) is divisible into two mappable units within the Snake River map area (Norris, 1982c). It is spectacularly exposed in the vicinity of upper Snake River and the headwaters of Knorr Creek. There, reconnaissance studies indicate that the lower unit is dominated by resistant, grey weathering, finely crystalline, stromatolitic limestone with interbeds of gypsiferous limestone, calcareous shale and siltstone. It lies in sharp, conformable contact with the underlying Katherine Group. The upper unit is dominated by dark grey, finely crystalline limestone, medium and light grey, finely crystalline dolomite, and variably thick, light grey weathering gypsum (Fig. 4.6). It is overlain disconformably by an interval of greenish grey, fine grained sandstone and

Figure 4.6. Upper Little Dal Formation (HLD2) *at GSC Section 106F9 in the Mackenzie Mountains immediately west of Snake River. Note very light colored gypsum bed pinching out from right to left. View is to the north. ISPG photo 662–80.*

pale red shale up to 50 m thick, marking the base of the Cambro-Ordovician Franklin Mountain Formation.

Pinguicula Group
(HP; *Table 4.1, Column 17*)

In the vicinity of the 65th parallel, immediately west of Snake River, is an impressive series of exposures of the Pinguicula Group (Norris, 1982c). The group rests with angular unconformity on the Werneckian Gillespie Lake Group (HG; Fig. 3.2). According to Eisbacher (1978), the succession can be divided into a number of mappable units. Upward from the base, these units are: basaltic flows and red, siliclastic laminites; buff weathering dolomitic siltstones; massive, light grey, stromatolitic limestone and dolomite; black shale with stromatolitic biostromes; and resistant quartzites with numerous interbeds of shale and dolomite. The section awaits further detailed study. Following Yeo et al. (1978), the authors consider that the Pinguicula Group is broadly equivalent to the Mackenzie Mountains Supergroup. The dividing line between them is the trace of the Snake River Fault. The Mackenzie Mountains Supergroup lies entirely to the east of it, the Pinguicula to the west of it, and the two groups are not known to be in contact. They are shown as approximately equivalent in Table 4.1 (Columns 17, 19) although that is far from proven. Differential allochthoneity with concomitant juxtaposition of contrasting facies may well be a factor compounding problems of their equivalence or correlation.

Tindir Group (lower part)
(HTI; *Table 4.1, Column 15A*)

Following Young (1982), we have adopted a basic, two-fold division of the Tindir. The lower part (HTI) is assigned to the Inuvikian Sequence and the upper part (HTI) to the Rapitanian (Tables 4.1, 4.2). Young (op. cit.) has divided the lower part of the Tindir into six informal units. Grey and purple, conglomeratic mudstones and siltstones at the base are overlain by grey and buff, stromatolitic dolomites and in turn, by grey and black shale grading upward into buff weathering, laminated dolomite.

The succeeding white and grey, massive to platy quartzarenites with brown and grey shale are followed by a thick, black to dark grey, pyritic shale with grey, stromatolitic limestone. Well bedded, buff and grey weathering, light grey dolomite and limestone cap the succession. Collectively this assemblage of fine to coarse clastics and stromatolitic carbonates bears a remarkable similarity to the Pinguicula Group and the lower part of the Mackenzie Mountains Supergroup (Young, 1982, p. 761). Correspondingly, it is presumed that the lower Tindir is mid-Helikian in age. Except for the uppermost carbonate unit, Young (op. cit.) reports diabase sills and dykes throughout the lower Tindir in the type area straddling the Yukon/Alaska border (see Fig. 3.17).

Unnamed ?mid-Helikian units in outcrop

Proterozoic sedimentary and igneous rocks of presumed mid-Helikian age are exposed in widely separated parts of the project area (Norris, 1985a). Insofar as their correlation to formally recognized map units is uncertain, they have been left unnamed, pending further study. Of the seven exposures or areas of exposure that will be discussed, two are singularly important; the south flank of Old Crow–Babbage Depression in the canyon of Porcupine River, and the east flank of Richardson Anticlinorium in Knorr Range. The five others are in the Aklavik Arch Complex: the Inuvik Airport quarry at the crest of the Complex, Richardson Mountains on its southeast flank, and White and Dave Lord uplifts and Keele Block, also on the crest.

Porcupine River Canyon (Table 4.1, Column 3)

Of the widely scattered exposures, the most celebrated are those in the canyon of Porcupine River in the vicinity of the international boundary (Fig. 4.7). Cairnes (1914) first reported on these outcrops through his participation in the boundary survey. He identified them as Tindir Group (s.l.) but he did not specify how they would correlate within the group. He noted the folded and faulted state of the rocks and recognized the difficulties in putting together a stratigraphic section with meaningful thicknesses for his units. Cairnes was struck by the scenic beauty of the outcrops of white to yellowish grey and pale red weathering, fine grained quartzites exposed in the canyon in the vicinity of Ramparts House and intruded by a steeply dipping, 10 m thick, dark green, highly sheared, diabasic dyke (Fig. 4.8). In association with these rocks, he observed the light to yellowish grey weathering dolomites and the soft, black shale (Road River Formation?) that appears to cap the succession. He constructed an approximate section of about 1200 m of "Tindir rocks" embracing the basic lithological units he observed along the river in the vicinity of the boundary.

W.P. Brosgé of the U.S. Geological Survey greatly extended Cairnes observations by boat in 1964, supplemented by D.K. Norris with helicopter support in 1980. Brosgé mapped from the upper end of the canyon, near the mouth of Caribou Bar Creek, to the Alaska border and beyond (W.P. Brosgé, pers. comm., 1980). He recognized the basic rock units described by Cairnes but placed them in a different order (Table 4.1, Column 3). From the base, his order was: a thick succession of brown sandstones (Pu1); massive, light grey, fine grained quartzite (Pu2); black, calcareous shale and limestone (Pu3); and pale yellowish grey and orange weathering dolomite (Pu4). It is suggested that the quartzite (Pu2) may correlate with Young's (1982) lower Tindir (HTi4) and, in turn, with the Inuvikian Katherine Group. The overlying black shale and limestone (Pu3) would correlate with Young's black shale (HTi5), and the dolomite (Pu4), with Young's dolostone (HTi6) capping the succession. On the other hand, the thick, black, calcareous shale (Pu3), cited by both Cairnes and Brosgé in the Porcupine River Canyon, looks strikingly similar to the lower Paleozoic Road River Formation and to the Upper Triassic Shublik. No fossils were found in either the shale or the associated limestone interbeds to resolve the problem of the age and correlation of this key unit.

Figure 4.7. *Brightly colored, unnamed Helikian? quartzites and dolomites in the canyon of Porcupine River immediately upstream from Ramparts House at the international boundary. View is to the east. ISPG photo 3590–1.*

Figure 4.8. *Dark brown weathering diabasic dyke in Helikian? quartzites on the right bank of Porcupine River immediately upstream from Ramparts House at the international boundary. GSC photo 3590–3.*

Knorr Range (Table 4.1, Column 17)

A succession of fine clastics and carbonates of unknown affinities and correlation is mapped in Knorr Range (Fig. 4.9; Norris, 1982b) in the southeast quarter of the project area. It is bounded by two major components of Richardson Fault Array: Knorr Fault on the west and Trevor Fault on the east. Insofar as some strands of the array have undergone right-lateral displacements of tens of kilometres along these faults in the middle and late Proterozoic, the succession is allochthonous and may have been transported many kilometres from its point of origin to the southeast as a consequence of Hayhookian orogenesis. It is approximately 2.9 km thick where measured (GSC

Figure 4.9. West face of Knorr Range from Margaret Lake. Dark grey, slaty argillite of unit P1 is exposed in the lower half of the range and resistant, orange and grey dolomite of unit P2 in the upper half. View is to northeast. GSC photo 1173–62.

Sections 106E2a, 2b, 2c and 106E10a). The succession lies, apparently unconformably, upon Little Dal Group and is overlain with regional unconformity by the Lower Cambrian Illtyd Formation.

The Knorr Range succession is divisible into at least three units (P1, P2 and P3). A 12 m thick quartzite pebble-conglomerate marks the base of P1. It is overlain by interbedded, dark grey to black, slaty argillite and olive grey siltstone, with interbeds of fine grained, argillaceous sandstone and fine grained, orange weathering dolostone. Coatings of malachite and azurite, associated with brecciation of the dolostone, were observed at about the middle of the succession and one dark brown, mafic dyke was noted. Unit P1 is 0.71 km thick and possibly disconformably overlies a continuous succession of pale olive-grey, finely to very finely crystalline, silty, dolomitic limestone and calcareous dolostone of the Little Dal Group.

Unit P2 gradationally overlies P1 and is readily divided into two parts: a lower, characteristically pale orange weathering, medium to dark grey, finely crystalline, silty dolostone with interbeds of dark grey, finely crystalline, brownish grey weathering limestone; and an upper, medium to dark grey, finely crystalline, medium to light grey weathering limestone with sparse interbeds of dolomitic limestone, dolostone and conglomeratic limestone. The lower part is 0.30 km thick and the upper part, 0.60 km for a combined thickness of 0.90 km for the unit.

Unit P3 is a thick succession of medium grey, finely crystalline limestone and dolomitic limestone, weathering pale yellowish grey, with interbeds of pale yellowish grey weathering dolomite and sparse, dark grey, slaty argillite and medium grey, fine grained quartzite. The limestone and dolomite are characteristically coarsely recrystallized into thick to massive beds with finely and coarsely crystalline textural lamination, and a few intervals of intraformational conglomerate. The unit is 1.26 km thick in Knorr Range and is overlain unconformably by medium grey, finely crystalline dolostone of the Lower Cambrian Illtyd Formation.

Pending additional study, the correlation of the Knorr Range succession with other known Helikian formations is unknown. The 12 m conglomerate at the base of P1 suggests that the succession lies disconformably upon Little Dal Group. Hence, it may be homotaxial with the Coates Lake Group of the Taiga-Nahoni Foldbelt. Alternatively, the characteristically recrystallized nature of Unit P3 might suggest correlation with Keele Formation as described in adjacent Ramparts River map area (Aitken et al., 1982). Thus, the thick shale succession comprising P1 would correlate with the combined Rapitan Group and overlying Twitya Formation, and the carbonates of Units P2 and P3 with the Keele (Table 4.1). The Sheepbed shale presumably would be absent at the sub-Cambrian unconformity.

Inuvik Airport Quarry (Table 4.1, Column 12)

At the west end of the runway at Inuvik Airport, quarrying for construction materials has provided extensive exposures of undivided Inuvikian rocks (Pu) on the crest of Campbell Uplift (Fig. 3.3; Dyke, 1975; Norris, 1981b; Chapter 13). The succession consists predominantly of pale red and olive grey, silty dolomitic argillite and argillaceous dolomite, commonly in beds 2 to 10 cm thick. Approximately 175 m of section are exposed. The only fossils reported are algal structures, presumably stromatolites, from near the top (Sproule, 1959), and their Helikian age can only be presumed. However, the virtual geomagnetic pole computed for these rocks (Norris and Black, 1964) would suggest an age of about 1.1 Ga. Subvertical fissures in the walls of the quarry are filled with pale yellow weathering bentonite, similar to that observed in lower Paleozoic rocks elsewhere in the uplift (Chapter 13). The succession dips 30° northwest beneath the Paleozoic on the north flank of the uplift. Its upper contact is not known to be exposed although it appears to have been penetrated in the Inuvik D-54 well, 12 km to the northwest (see below). Its lower contact with still older Proterozoic layered rocks (Werneckian?) is inferred, from seismic reflection studies (Cook et al., 1987), to occur at a depth of about 5 km, making the type Inuvikian Sequence about 3 km thick.

Northern Richardson Mountains

At the headwaters of Rat River, in northwestern Fort McPherson map area (Norris, 1981c), is an isolated outcrop of carbonates and clastics (?H1) arbitrarily assigned to the Inuvikian Sequence (Fig. 4.1). The 180 m thick succession consists of medium and light grey, finely crystalline limestone and dolomite, with interbeds of pale red argillite, siltstone and fine grained sandstone. It is locally highly sheared and appears to be fault-bounded on at least two sides. Insofar as it is embraced within the Richardson Fault Array it is considered allochthonous with neither stratigraphic top nor base.

White Uplift (Table 4.1, Column 7)

The only exposed Proterozoic (Inuvikian?) rocks (Pu) associated with White Uplift occur locally on its northwest flank. Dyke (Chapter 13) reports bedded dolomite with red and orange weathering quartzite and a 100 m thick, dark green, mafic volcanic and volcaniclastic unit. The succession is broken up by high-angle faults cutting both Precambrian and lower Paleozoic strata. It is overlain with apparent angular unconformity by Lower Cambrian (Fritz, 1974) shale, siltstone and quartzite. The succession was not identified on the Bell River, 1:250 000 scale geological map (Norris, 1981d) because field notes relating to it were lost in the fire at Margaret Lake in 1970. However, the succession has been identified on the 1:500 000 scale geological compilation of the Operation Porcupine project area (Norris, 1985a) and the data have been updated by L.D. Dyke (Chapter 13, Fig. 13.9).

Dave Lord Uplift (Table 4.1, Column 6)

Outcrops of Proterozoic rocks are confined to the southwest end of the uplift in Canada and to the northwest flank. The southwestern localities are Wernecke Supergroup (HW) unconformably overlain by lower and middle Paleozoic carbonates (ЄDb). At Lone Mountain, on the northwest flank of the uplift, massive, dark green, amygdaloidal basalt and brown weathering quartzite (?Pu) occur as a horse within the Yukon Fault Zone. Neither the top nor the base of the basalt is exposed. Its mild cleavage and apparent hydrothermal alteration are in stark contrast with the relatively fresh Tertiary or Quaternary olivine basalt (Brosgé and Reiser, 1969) in the vicinity of the Porcupine River in Alaska, 25 km west of the international boundary. Insofar as activity on the Yukon Fault was at least locally mid- to Late Cretaceous in age, it is suggested that these volcanics on Lone Mountain could be as young as Early Cretaceous. On the other hand, they could possibly be as old as Proterozoic. They are mentioned here solely for completeness of the record.

Keele Block (Table 4.1, Column 5)

Both Werneckian and Inuvikian clastics are observed to underlie lower and middle Paleozoic limestones in the Keele Block (Fig. 4.1). Extensive areas of Wernecke Supergroup (HW) occur at the headwaters of Salmon Fork River. Northwest of there, in the Bluefish River drainage basin, are sparse outcrops of light grey to pale greyish brown, medium grained, rusty brown weathering, flaggy quartzite (?Pu), similar to that in Dave Lord Uplift. Contact relations with overlying formations were not observed although they are regionally unconformable. The previously discussed deformed clastic rocks, in the canyon of Porcupine River in the vicinity of the international boundary, bear closest resemblance to those described here.

Barn Uplift and Eagle Foldbelt (Table 4.1, Columns 4, 16)

No Proterozoic rocks are known to be exposed in these two tectonic elements although they can be anticipated to occur at depth to fill the gap between surface rocks and the Hudsonian basement. Because Inuvikian clastics and carbonates are widespread in the north half of the project area, they are presumed to lie immediately beneath the lower and middle Paleozoic rocks exposed in Barn Uplift. They appear to be absent beneath Eagle Foldbelt in the south half of the area because Werneckian rocks occur immediately beneath Paleozoic strata on the west, south and east flanks of the belt.

Unnamed ?mid-Helikian and Hadrynian units in boreholes

Proterozoic igneous and sedimentary formations have been penetrated in at least five deep wells in the project area and may have been penetrated in five other wells (Pugh, 1983; Wielens, 1987). Moreover, crustal seismic reflection profiles from the northern Interior Platform immediately east of the project area depict older, layered deposits (Cook, 1988) that may be Wernecke Supergroup.

The Helikian formations in the subsurface of the lower Mackenzie River region (Table 4.1, Column 20) have been categorized by Pugh (1983) into four distinct lithologic units, referred to informally from oldest to youngest as Shale (S), Dolomite (D), Argillite (A) and Orthoquartzite (Q). The identification of Hadrynian strata, on the other hand, is less certain. Volcanic rocks beneath Tuktoyaktuk Peninsula may correlate with them. Insofar as the penetrations provide limited information on the rocks at the bottom of these boreholes, the correlation and interpretation of the age of the formations involved is necessarily tentative.

Nonetheless, Pugh's four-fold division of the Helikian encountered in the wells appears to match the four units of the Pinguicula and the lowermost four units of the lower Tindir Group (Table 4.1; Young, 1982). Thus, Pugh's Shale correlates with Young's purple and grey mudstones at the base of the lower Tindir and with the basal unit of the Pinguicula; his Dolomite with the dolostone unit; his Argillite with the dolostone and shale unit; and his Orthoquartzite with Young's quartzite and shale unit.

Of the five deep wells that have penetrated the Proterozoic (Fig. 4.1), four bottomed in the Helikian and one possibly in the Hadrynian. The deepest penetration into the Helikian occurred in the Atlantic et al. Arctic Circle Ontaratue H-34 well in the northern Interior Platform. There, according to Pugh (1983), 876 m of argillite (A) overlie 89 m of dolomite (D) at the bottom of the hole. In eastern Richardson Anticlinorium, Gulf Mobil Caribou YT N-25 penetrated 167 m of fine grained, variably dolomitic quartzite, presumably from the topmost unit of Pugh's generalized Proterozoic succession (op. cit.).

Two wells in the Aklavik Arch Complex, Amoco Ulster Scurry Inuvik D-54 and IOE Eskimo J-07, also penetrated the Helikian. In the former, adjacent to Mackenzie Delta, 280 m of interbedded black, red and green shale and quartz sandstone with a basal quartzite pebble conglomerate (Lower Cambrian?) overlie 127 m of clear quartzite and red and green shale at the bottom of the hole. It is suggested that the clastics below the conglomerate are Inuvikian and that they belong to Pugh's orthoquartzite (Q). They appear to have been removed from the crest of Campbell Uplift by pre-Cambrian erosion. In the J-07 well, about 100 km northeast along the arch complex, 78 m of mafic volcanic rocks and volcaniclastics have been drilled immediately beneath the sub-Mesozoic unconformity. Should they be coeval with the Coppermine Basalts (Sevigny et al., 1991), they would be mid-Proterozoic (1268 Ma) in age, that is, older than the Inuvikian Mackenzie Mountain Supergroup inferred in the D-54 well. On the other hand, in the Inexco Husky et al. Porcupine Y.T. G-31 well in western Taiga-Nahoni Foldbelt, close to the Alaska border, the quartzite and red and green shale at the bottom of the hole may be Hadrynian upper Tindir Group (see below) although no extrusive rocks have been reported from this well.

In five additional wells on the Aklavik Arch Complex (Wielens, 1987), the penetration of Precambrian rocks is less certain. These are Gulf East Reindeer P-60 and C-38, Gulf Mobil East Reindeer G-04 and A-01, and Gulf Mobil Ogeoquoq J-06. All are on the crest of the arch complex immediately east of Mackenzie Delta. The interbedded quartzites, dolomite and red and green shale in which they bottomed could be Lower or Middle Cambrian Mount Clark or Mount Cap formations. On the other hand, the lithologies are similar to those assigned to the Helikian Orthoquartzite unit in the Inuvik D-54 well.

The Rapitan and Hay Creek groups (Table 4.1, Column 19)

Rapitanian sedimentary and igneous rocks are known from the four corners of the project area. Within the terms of reference of this volume, the sequence is best known in Snake River map area (Norris, 1982c). There, it embraces the Rapitan Group and the overlying Hay Creek Group (Yeo et al., 1978, p. 227). Following Yeo et al. (op. cit.) and Aitken et al. (1982), the name "Rapitan" is used in its original intent (Green and Godwin, 1963), to include only the mixtites, mudstones, conglomerates and iron formation. The overlying Twitya, Keele and Sheepbed formations are embraced within the Hay Creek Group (Table 4.2), the youngest rocks known to occur beneath the Cambrian in the project area. Collectively, the Rapitan and Hay Creek comprise the Rapitanian Sequence in the southeast corner of the project area.

The Rapitan Group, dominated by clastic rocks, is in marked contrast to the thick carbonate succession of the Little Dal below it. According to Calstan geologists (Crest, 1963) the Rapitan is 2.0 km thick in the vicinity of Snake River. Locally, it is divisible into two formations. The lower one (**HR1**; Sayunei Formation; Fig. 4.10) consists predominantly of pale red, hematitic conglomerate and siltstone, including both mafic and felsic igneous clasts. It is 0.6 to 0.9 km thick. Hematite-jasper iron formation, with abundant extrabasinal dropstones, is concentrated in three main zones in the lower 0.3 km of the unit. The total iron formation reaches a maximum thickness of 85 m immediately west of Snake River. The upper formation (**HR2**; Shezal Formation) comprises a massive, greyish green diamictite. It is over 1 km thick and contains clasts of dolostone, mafic intrusive rocks, quartzite and shale that are rounded to subangular and range from sand size to boulders up to 5 m long. Numerous clasts are striated and glacially polished (Eisbacher, 1981).

Figure 4.10. Diamictite of the lower Rapitan Group (HR1; Sayunei Formation) east of Snake River in the Backbone Ranges of Mackenzie Mountains. Clasts are predominantly quartzite and dolomite. ISPG photo 662-42.

No sections of the overlying Hay Creek Group have been studied. Exposures are excellent and are confined to the Backbone Ranges at the headwaters of Cranswick River in the extreme southeast corner of the project area (Norris, 1982c). There, the succession is assigned to the Twitya, Keele and Sheepbed formations, although some of the mapped Twitya may actually be part of the upper Rapitan Group. Interbedded shale, siltstone and sandstone (Twitya, **HT**) is overlain gradationally by a resistant sequence of interbedded dolostone and quartzite (Keele, **HK**) and, in turn, by recessive weathering dark grey shale (Sheepbed, **HS**) in the immediate hanging wall of the Backbone Fault (op. cit.). The whole is overlain unconformably by the Lower Cambrian Backbone Ranges(?) Formation.

Tindir Group (upper part) (**HTI**; *Table 4.1, Column 15A*)

The Rapitanian Tindir Group along the Alaska border, in the extreme southwest corner of the project area, is divisible into five formations (Young, 1982). The most complete section lies in Canada at the headwaters of Tindir Creek. A discontinuous unit of amygdaloidal basalt (HTI1) is overlain by purple mudstone (HTI2) with minor diamictite (Fig. 4.11), and with thin hematite–jasper iron formation at the top in some areas. This is followed upward by purple and red diamictite with thin interbeds of purple mudstone and chert (HTI3). Conformably overlying this is a turbiditic succession of grey and green shale (HTI4), with interbeds of dolomitic sandstone, thin diamictite and volcanic breccia. The topmost unit (HTI5) is in gradational contact with beds below and is characterized by wavy bedded, fetid limestone with purple, pale red and grey shale interbeds. The group is overlain disconformably by the Cambro-Ordovician Jones Ridge Formation (Chapter 6).

As pointed out by Young (1982) there are many striking similarities between his five formations of the upper Tindir Group along the Alaska border and the five-fold divisions of the Rapitan and Hay Creek groups in northwestern Mackenzie Mountains. The correlation of the Rapitanian Sequence across Yukon Territory, from Mackenzie Mountains to western Taiga–Nahoni Foldbelt, would appear reasonably certain in spite of the sequence being absent or not recognized in many intervening inliers (Fig. 4.1). It is absent, for example, from the core of Blackstone and Bouvette anticlines (Fig. 4.1; Norris, 1982d), as well as from the large, unnamed structural culmination (Fig. 4.3) in Ogilvie Mountains just west of Mount Klotz, at the headwaters of the Tatonduk River. Fine grained, grey and greenish grey clastic rocks immediately beneath Paleozoic strata along the Ogilvie River in Skookum Jim Anticline (Fig. 4.1), moreover, are not diagnostic of any of the Coates Lake (Jefferson and Ruelle, 1986), Hay Creek or Harper (Roots, 1987) groups.

Figure 4.11. Thin diamictite beds in Young's (1982) purple mudstone unit (HT2) of the upper part of the Tindir Group on Tatonduk River, Alaska. ISPG photo 3590–7.

Immediately south of the project area, along the south and west margins of the broad, east-trending inlier termed the Coal Creek Dome (Green, 1972) are up to 2500 m of sedimentary and volcanic strata, informally called the "Harper group" (Mustard et al., 1988, p. 198). They are unconformity-bounded, Rapitanian rocks (HHa) coeval with the upper Tindir Group of the Nahoni Range (Table 4.1, Columns 15A, 15B).

In the Nahoni Range, at the headwaters of Miner River (GSC Section 116G13), interbedded pale greyish-green and red stromatolitic dolomite, red and green sandstone and conglomerate, and at least one mafic volcanic flow are exposed immediately beneath lower Paleozoic carbonate rocks. The association of lavas and conglomerates in the measured section is suggestive of either the Harper or upper Tindir groups. Moreover, the 751 Ma age for a felsic flow in the "Harper Group" (Roots, 1987) would suggest that the upper Tindir and the Harper were coeval, thereby expanding greatly the region underlain by the Rapitanian in the southwest corner of the project area.

As cited earlier, in the subsurface of Porcupine Anticline in the northern Ogilvie Mountains (Norris, 1981a), the red and green shales penetrated in the Y.T. G–31 well could also be upper Tindir Group. However, the positive correlation of disparate sections of the upper Tindir along the Alaska border is by no means proven.

Neruokpuk Formation (PN; *Table 4.1, Column 2*)

Beyond the Aklavik Arch Complex, in the core and on the south flank of Romanzof Uplift, there are possible correlatives of the Rapitanian upper Tindir Group (Fig. 4.1). They are contained within the Neruokpuk Formation as mapped by Norris (1981e, f). However, significant discoveries of fossils in structurally depressed blocks of Road River and younger formations on the north flank of the uplift (Norris, 1976, 1986; I. Tailleur, pers. comm., 1986; Lane and Cecile, 1989) have greatly reduced the area implied to be underlain by the Precambrian Neruokpuk Formation as well as the number of units said to be Neruokpuk. In spite of the pruning, only about 3 km of section (Lane and Cecile, 1989) have been removed from the 13 to 14 km originally estimated to be the composite thickness of the formation. Virtually all of

Norris's informal unit PN2[1] of the Neruokpuk is now known to be Road River Formation or Endicott Group. Only units PN4, PN5 and possibly PN6, underlying the crest and southwest flank of the uplift are currently considered to be Neruokpuk. Unit PN4 is overlain by Lower and Upper Cambrian volcanic conglomerate with thin mafic flows and limestone lentils on Whale Mountain (Norris, 1981f). It is thrust northward over PN5 and PN6 on the Firth Fault so that PN5 and PN6 would appear to be the younger units. All three are presumed to be late Precambrian (Hadrynian) or at least no younger than late Early Cambrian, the oldest age of the limestones (Norris, 1985b).

The only measured sections of the Neruokpuk are on the ridges above Glacier and Wolf creeks, tributaries to Firth River in the Herschel Island and Demarcation Point map area (Norris, 1981f). Section 117C4 embraces 1300 m of informal unit PN5 above Glacier Creek in the immediate footwall of the Firth Fault and 117C1 some 5100 m within PN4 in the hanging wall. Definition of Unit PN6 is based on air photo interpretation. It was not studied on the ground.

PN4 consists of interbedded olive grey, fine to medium grained quartz arenite, slaty grey and red argillite and olive-grey chert. It is overlain by and would appear to intertongue with PN5, a thick succession of interbedded black, finely crystalline, yellowish grey weathering limestone and slaty grey and red argillite. Samples of a highly altered, dark green, mafic dyke cutting PN5 on Firth River (GSC loc. 80697), supplied by geologists of Imperial Oil Ltd., gave a whole rock Rb-Sr age of 93 ± 13 Ma. Samples of limestone from PN4 west of Firth River (GSC loc. 11265) contained no conodonts.

Correlation of the Neruokpuk with late Precambrian or Eo-Cambrian formations across the Kaltag Fault and Aklavik Arch Complex is purely speculative. However, it is tantalizing to suggest that the thick clastic succession embraced within PN4 might be coeval with the turbidites of Unit HTI4 (Young, 1982) of the upper Tindir, and correspondingly, the limestone and shale of PN5 might be coeval with Young's unit HTI5 (Table 4.1). Whatever the correlation and age of the Neruokpuk, a significant part of the record of the geological evolution of the extreme northwest corner of the ancestral North American Plate is contained within the Rapitanian and part in the Inuvikian and Werneckian sequences. What remains to be done is to establish in absolute terms the time frame within which Proterozoic sedimentation and deformation took place.

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[1] The original numbering scheme (PN0–PN6) for the Neruokpuk Formation in Romanzof Uplift was determined by the apparent structural order from lowest to highest, that is from north to south, in the direction of the regional dip. The numbering is now simply a relict nomenclature serving to tie these early Paleozoic and older units to the published geological maps.

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Middle Cambrian Slats Creek Formation resting with right-angular unconformity upon vertically dipping, Helikian Quartet Group along upper Hart River, Y.T. View is to the northeast. GSC photo 3-11-70.

CHAPTER 5

CAMBRIAN

W.H. Fritz

Fritz, W.H., 1996. Cambrian. In The Geology, Mineral and Hydrocarbon Potential of Northern Yukon Territory and Northwestern District of Mackenzie. Geological Survey of Canada, Bulletin 422, p. 85–117.

Abstract

The initial Cambrian record in most of the project area consists of medial *Bonnia-Olenellus* Zone and younger Lower Cambrian strata overlying a Precambrian surface of various ages. The Richardson Trough came into existence during an Early Cambrian transgression, and continued to function as a negative entity, separating the Mackenzie Platform to the east from the Yukon Block to the west. On the Mackenzie Platform, a thin Lower and Middle Cambrian clastic succession (Macdougal Group) is overlain by Upper Cambrian and younger dolostone (Franklin Mountain Formation). The Richardson Trough contains Lower Cambrian limestone (Illtyd Formation, new name) that grades upward though massive mounds into Middle? and Upper Cambrian basinal platy limestone and shale (Road River Formation). In the Yukon Block, siltstone and clean, thick bedded Lower Cambrian limestone of the Illtyd Formation is overlain by Middle Cambrian fine to coarse grained clastics of the Slats Creek Formation (new name). Slats Creek deposition reflects block faulting, whereas the overlying Taiga Formation (new name), comprising Middle and lower Upper Cambrian clastics and carbonates, represents the process of a return to more uniform depositional conditions. The Taiga Formation is overlain by an unnamed thick succession of Upper Cambrian through Lower Devonian clean carbonates (ЄDb), not unlike the clean carbonate within the Illtyd Formation below. The British–Barn Trough is north of the Yukon Block, and separated from it by the Kaltag Fault. There the Cambrian is within a poorly dated succession of volcanics and basinal clastics. The volcanics can be lithologically correlated with strata in Alaska which contain Lower and Upper Cambrian fossils. Recent reconnaissance mapping has outlined several areas underlain by basinal argillites containing Lower(?) Cambrian trace fossils. In the southern part of the region, outcrops which have been mapped as Road River Formation may contain some Cambrian strata.

Résumé

Les premiers vestiges du Cambrien dans la grande partie de la région à l'étude comportent une zone intermédiaire à *Bonnia-Olenellus* et des couches plus récentes du Cambrien inférieur reposant sur une surface précambrienne d'âges divers. La cuvette de Richardson est apparue durant une transgression du Cambrien précoce et est demeurée une entité négative, séparant la plate-forme de Mackenzie à l'est du bloc du Yukon à l'ouest. Sur la plate-forme de Mackenzie, une mince succession clastique du Cambrien inférieur et moyen (Groupe de Macdougal) est recouverte de dolomie du Cambrien supérieur et d'époque plus récente (Formation de Franklin Mountain). La cuvette de Richardson contient du calcaire du Cambrien inférieur (Formation d'Illtyd, nouveau nom) qui se transforme vers le haut, à travers des monticules massifs, en un calcaire et un shale feuilleté de bassin du Cambrien moyen? et supérieur (Formation de Road River). Dans le bloc du Yukon, le siltstone et le calcaire pur en strates épaisses du Cambrien inférieur de la Formation d'Illtyd reposent sous des roches clastiques à grain fin à grossier du Cambrien moyen de la Formation de Slats Creek (nouveau nom). Le dépôt de la Formation de Slats Creek indique un morcellement par failles tandis que la Formation de Taiga (nouveau nom) sus-jacente, comprenant des clastites et des roches carbonatées du Cambrien moyen et de la partie inférieure du Cambrien supérieur représente un retour à des conditions de sédimentation plus uniformes. La Formation de Taiga repose sous une succession épaisse non désignée de roches carbonatées pures (ЄDb) du

Cambrien supérieur-Dévonien inférieur, qui ressemblent aux roches carbonatées pures de la Formation d'Illtyd sous-jacente. La cuvette de British-Barn est située au nord du bloc du Yukon et en est séparée par la faille de Kaltag. Là, le Cambrien se trouve dans une succession mal datée de volcanites et de clastites de bassin. Les volcanites peuvent être lithologiquement corrélées à des couches de l'Alaska qui contiennent des fossiles du Cambrien inférieur et supérieur. Des travaux récents de cartographie de reconnaissance ont permis de délimiter plusieurs régions reposant sur des argilites de bassin qui contiennent des ichnofossiles du Cambrien inférieur(?). Dans la partie méridionale de la région, les affleurements qui ont été cartographiés comme la Formation de Road River peuvent contenir des couches cambriennes.

INTRODUCTION

The Cambrian of the northern Yukon and northwestern District of Mackenzie has been divided into four major depositional regions, shown in Figure 5.1. The boundaries and the names given to the regions are only slightly different from those used by Lenz (1972, fig. 2) in his description of Ordovician to Devonian strata in the same area. The easternmost region, the Mackenzie Platform, extends beyond the eastern and southeastern margins of the map area. Its northern boundary is unknown because of a lack of subsurface data. West of the Mackenzie Platform Region is the Richardson Trough, which is believed to have opened into both the Selwyn Basin to the south and the British-Barn Trough to the north.

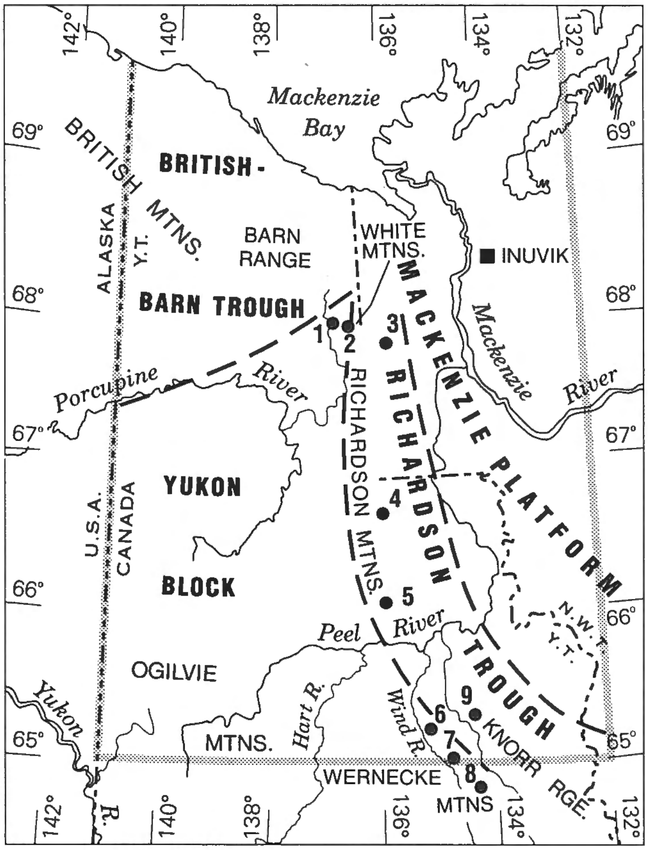


Figure 5.1. Index map showing the four major regions of Cambrian deposition, and the location of stratigraphic sections (solid circles).

The Yukon Block is west of the Richardson Trough and extends beyond the Yukon/Alaska border. Jeletzky (1962, fig. 2) named this region the "Yukon Stable Block", but the abridged name adapted in this chapter is deemed more appropriate because of the region's history of tectonic instability during Middle Cambrian time. The British-Barn Trough abuts the other three regions and is part of the Franklinian Orogen.

Formations within the four regions and their relative ages are shown in Figure 5.2. A striking aspect in all four regions is the absence of uppermost Precambrian and lowermost Cambrian strata. The oldest Cambrian strata documented thus far belongs to the medial part of the late Early Cambrian *Bonnia-Olenellus* Zone.

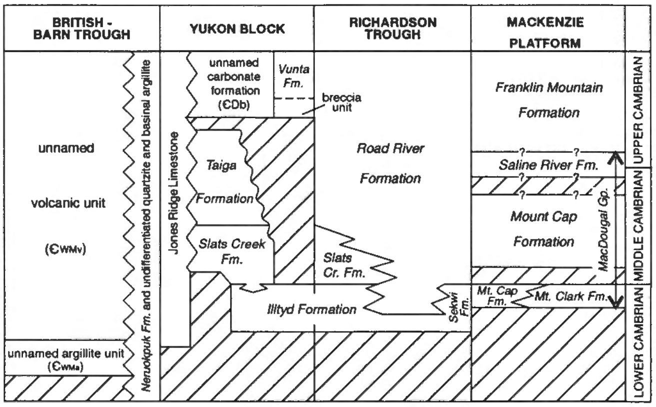


Figure 5.2. Correlation chart for Cambrian formations within the northern Yukon Territory and northwestern District of Mackenzie study area.

The measured stratigraphic sections are located in Figure 5.1 and shown in Figures 5.3 and 5.4. For ease of location, they have been numbered from north to south (approximately). These same numbers are used in the text where they are accompanied by an additional set of numbers [i.e., 106F13, the first number is a map sheet number (National Topographic System); the second number locates the section on the geological map].

The important fossils and their ages are given in the text along with the stratigraphic descriptions. A detailed list of fossils is provided in Appendix 1 along with their locality numbers. These numbers are also shown opposite the stratigraphic sections in Figures 5.3 and 5.4.

MACKENZIE PLATFORM

General Statement

Within the map area (Fig. 5.1), the Cambrian of this region is mainly in the subsurface; the formations are best known from exposures located to the southeast. The Cambrian formations are shown in Figure 5.2. The Mount Clark, Mount Cap, and Saline River formations comprise the restricted Macdougal Group. The Sekwi Formation is allochthonous on the Mackenzie Platform, having been thrust in from the Richardson Trough. That formation will be discussed under the Richardson Trough.

Macdougal Group

The Macdougal Group has been relegated to questionable status (Aitken et al., 1973, p. 16, 28). The group was formally introduced by Hume (1954, p. 9), who's data were derived from unpublished work by A.W. Nauss. The base of the Group was placed at the base of a 40 m thick, "chocolate-coloured" shale unit and the top was located between a 15 m, dark grey limestone unit and the overlying dolostone of the Franklin Mountain Formation. At the type section of the Macdougal Group, in Dodo Canyon, Aitken et al. (1973, p. 16) discovered a major unconformity between the "chocolate-coloured" shale, which they assigned to the Helikian, and the overlying Cambrian. Instead of omitting the "chocolate-coloured" shale from the group, Aitken et al. (1973, p. 28) chose to regard the group as "obsolete". I prefer to recognize a restricted Macdougal Group, with the base located at the base of the Cambrian (Aitken et al., 1973, Pl. 16 for basal Cambrian contact) and extending to the base of the Franklin Mountain dolostone. Thus defined, the group is bracketed by distinct contacts, whereas the contacts between formations within the group are less obvious because they are commonly covered, and in some areas lateral facies changes complicate contact relationships.

Mount Clark Formation

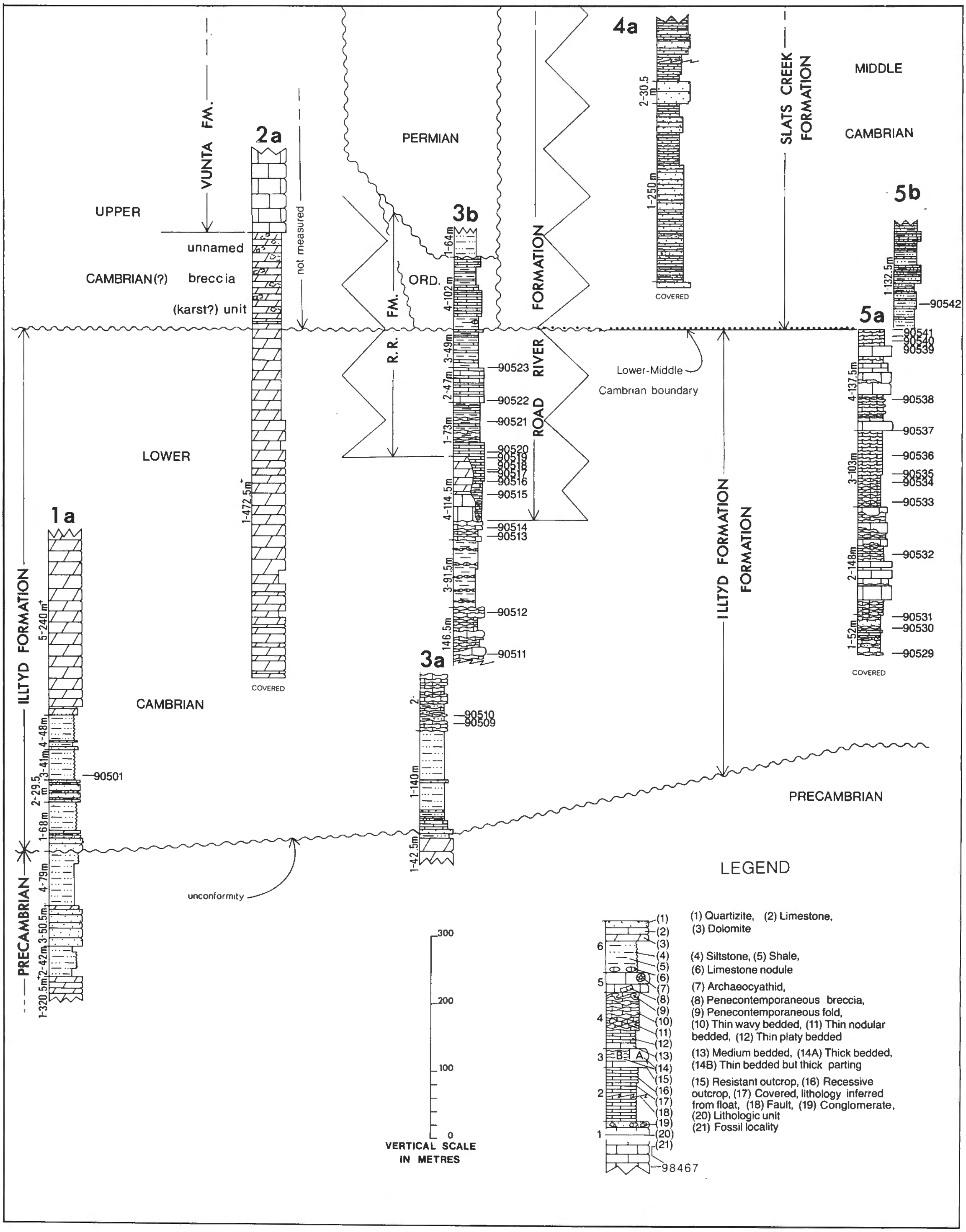
Descriptions of the Mount Clark and other formations within the Macdougal Group refer to outcrops a short distance southeast of the map area (Aitken et al., 1973). Within the map area, the formations are mainly covered by younger strata. In the southeastern part of the map area, the Macdougal Group is absent because of erosion or nondeposition over the Mackenzie Arch.

At the type section in the Wrigley Lake area (Williams, 1923), the Mount Clark Formation comprises white, purplish and reddish grey sandstones that exceed 215 m in thickness (Aitken et al., 1973). *Olenellus* sp. in the overlying shale and *Skolithos* within the formation testify to its Early Cambrian age. The basal Mount Clark beds display an angular relationship with the underlying Precambrian strata.

The Mount Clark Formation is tentatively correlated with the basal Paleozoic sandstone assigned to the Old Fort Island Formation, which has its type locality on the western shore of Great Slave Lake. No diagnostic fossils are known from the Old Fort Island Formation.

Mount Cap Formation

The type section of Mount Cap Formation consists of "100 feet or more of green and rusty, thin bedded sandstone and overlying grey and rusty shale or phyllite" (Williams, 1922, 1923) that overlie the Mount Clark Formation. The top of the formation is not exposed at the type section, but elsewhere the Mount Cap is overlain by the Saline River Formation. Fossils from various localities within the Mount Cap Formation range from the late Early Cambrian *Bonnia–Olenellus* Zone to the Middle Cambrian *Glossopleura* Zone (Aitken et al., 1973, p. 29). At Dodo Canyon the Mount Cap contains a disconformity in which the Middle Cambrian *Plagiura–Poliella* Zone and lower half of the *Albertella* Zone are missing (Fritz, 1970). As mentioned earlier, the Mount Cap is, in part, the lateral equivalent of the Mount Clark Formation. Where the two formations are present, the clean, light coloured sandstone of the Mount Clark underlies the Mount Cap. Where only the Mount Cap is present, Lower Cambrian argillaceous sandstone,



a

Figures 5.3a, b. Stratigraphic sections mainly showing distribution of the Illtyd Formation.

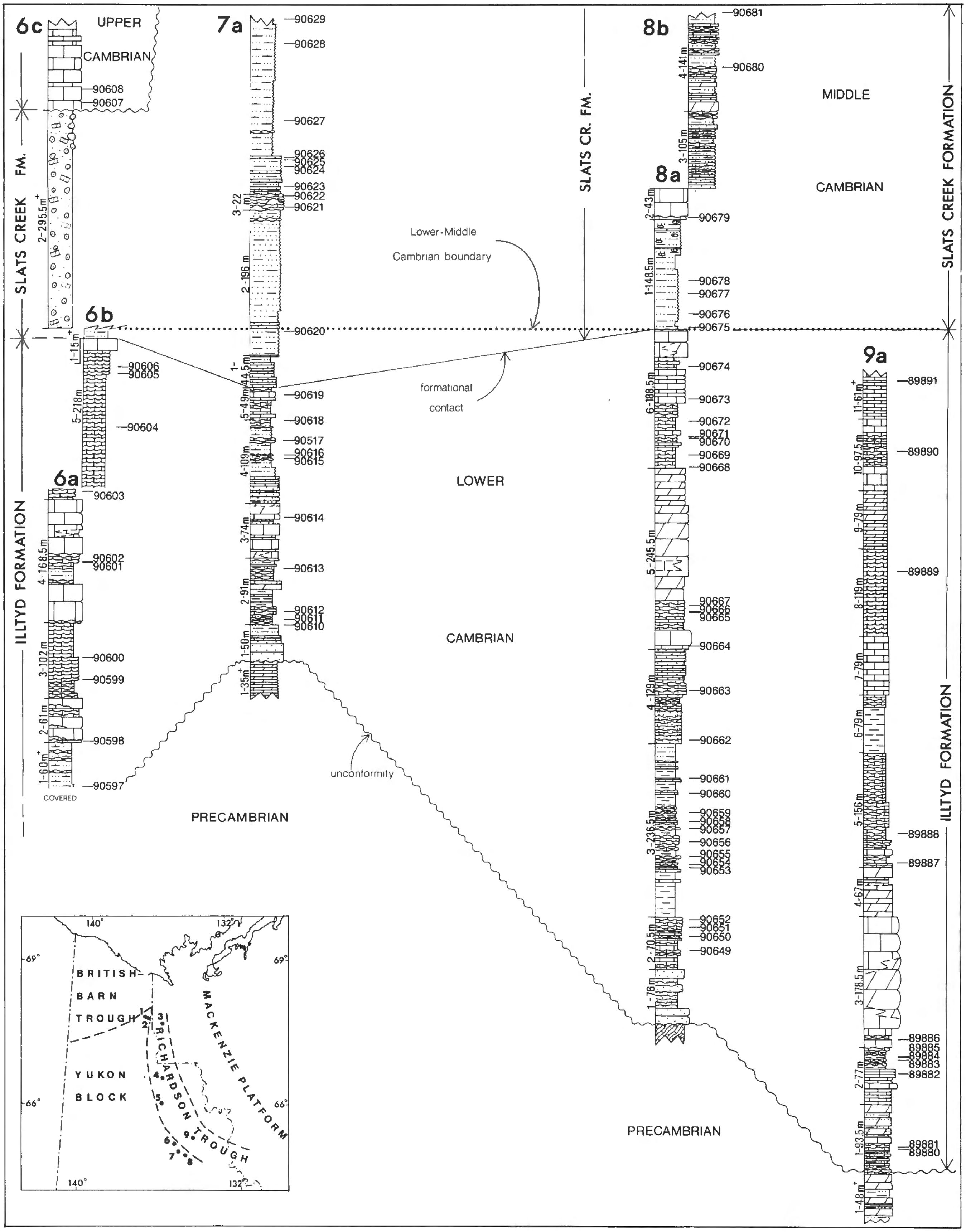


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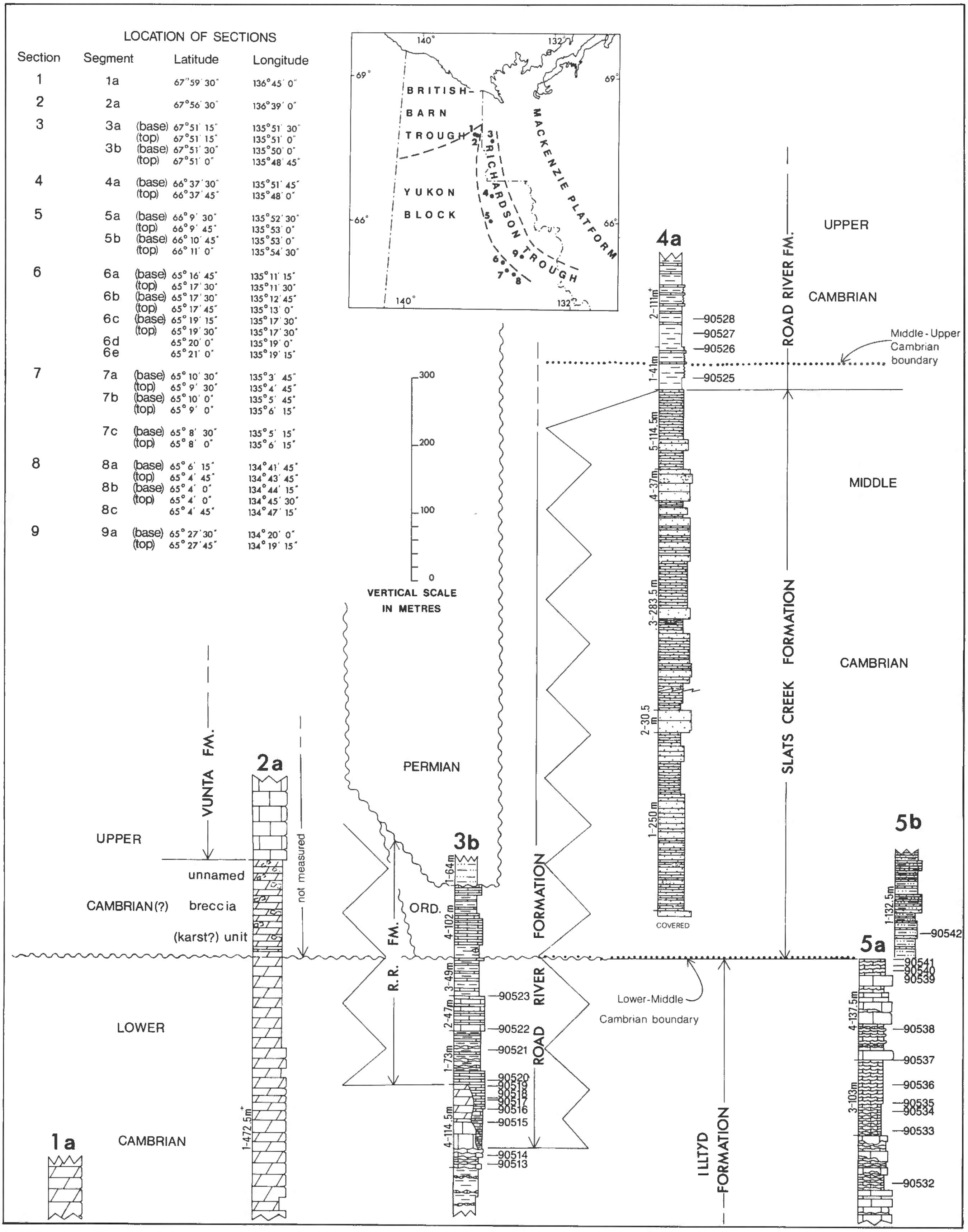
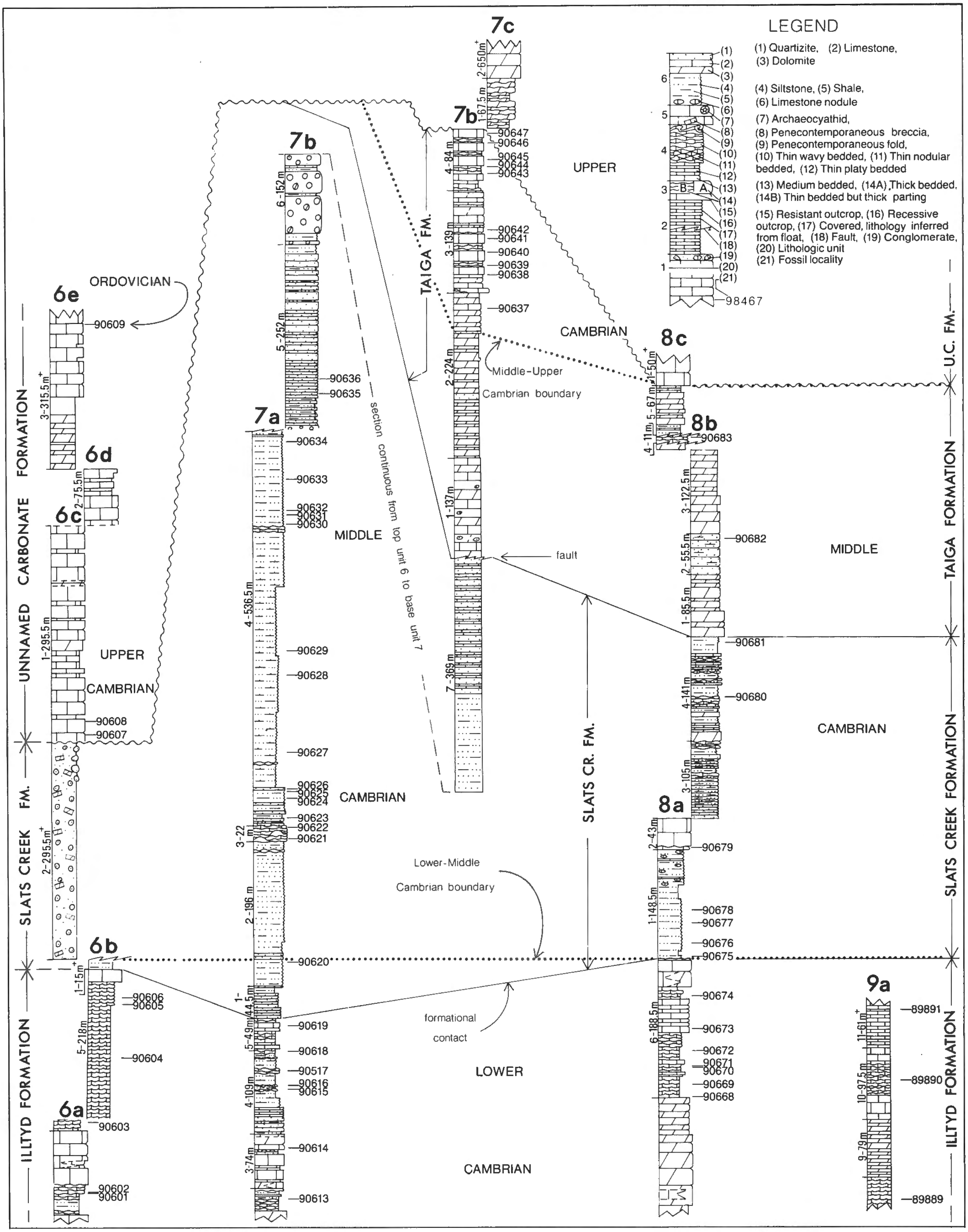
Figure 5.3. (cont'd.)


LOCATION OF SECTIONS

Section	Segment		Latitude	Longitude
1	1a		67°59' 30"	136°45' 0"
2	2a		67°56' 30"	136°39' 0"
3	3a	(base)	67°51' 15"	135°51' 30"
		(top)	67°51' 15"	135°51' 0"
	3b	(base)	67°51' 30"	135°50' 0"
		(top)	67°51' 0"	135°48' 45"
4	4a	(base)	66°37' 30"	135°51' 45"
		(top)	66°37' 45"	135°48' 0"
5	5a	(base)	66°9' 30"	135°52' 30"
		(top)	66°9' 45"	135°53' 0"
	5b	(base)	66°10' 45"	135°53' 0"
		(top)	66°11' 0"	135°54' 30"
6	6a	(base)	65°16' 45"	135°11' 15"
		(top)	65°17' 30"	135°11' 30"
	6b	(base)	65°17' 30"	135°12' 45"
		(top)	65°17' 45"	135°13' 0"
	6c	(base)	65°19' 15"	135°17' 30"
		(top)	65°19' 30"	135°17' 30"
	6d		65°20' 0"	135°19' 0"
	6e		65°21' 0"	135°19' 15"
7	7a	(base)	65°10' 30"	135°3' 45"
		(top)	65°9' 30"	135°4' 45"
	7b	(base)	65°10' 0"	135°5' 45"
		(top)	65°9' 0"	135°6' 15"
	7c	(base)	65°8' 30"	135°5' 15"
		(top)	65°8' 0"	135°6' 15"
8	8a	(base)	65°6' 15"	134°41' 45"
		(top)	65°4' 45"	134°43' 45"
	8b	(base)	65°4' 0"	134°44' 15"
		(top)	65°4' 0"	134°45' 30"
	8c		65°4' 45"	134°47' 15"
9	9a	(base)	65°27' 30"	134°20' 0"
		(top)	65°27' 45"	134°19' 15"

a

Figures 5.4a, b. Stratigraphic sections mainly showing distribution of Slats Creek and Taiga formations.



b

Figure 5.4. (cont'd)

siltstone and interbedded shale of the Mount Cap overlie an erosional surface on the Precambrian.

Saline River Formation

The type section for the Saline River Formation (Williams, 1923) consists of poor exposures of red and green shale with salt and gypsum casts along the Saline River (Franklin Mountains). There the lower contact of the Saline River is covered and the upper contact is gradational with the Franklin Mountain Formation (Aitken et al., 1973, p. 30). The Saline River Formation is reported to unconformably overlie strata ranging in age from the Early Cambrian to Helikian (Katherine Group; op. cit., p. 31). The maximum thickness of the Saline River is 162 m in the Franklin Mountains, and 97 m in the Mackenzie Mountain Front (op. cit., p. 30, 98). No diagnostic fossils have been found in Saline River strata.

Aitken et al. (1973, p. 30) favor placing the Saline River in the Late Cambrian because of the formation's gradational relationship with the overlying Franklin Mountain Formation, but they have not ruled out a Middle Cambrian age. They (op. cit., p. 31) suggested "that the Saline River accumulated in paleotopographic lows as the earliest deposits following a pre-Late Cambrian tectonic event." Sandstone units in the Nahanni map area to the southeast (Fritz, 1981, Section 3, Rockslide Formation, Unit 5 and Rabbitkettle Formation, Units 1, 2) may be a record of this event. There, sandstone enters the stratigraphic record in the upper *Bolaspidella* Zone (upper Upper Cambrian), peaks in the *Cedaria-Crepicephalus Zone*, and wanes in the *Aphelaspis* Zone (*C.-C.* Zone and *A.* Zone = lower Upper Cambrian Dresbachian Stage). No similar sandstones were noted in the Road River Group in the Selwyn Basin or in the Richardson Trough. In the Yukon Block, some pebble sized clasts from a local uplift were noted in the *Cedaria-Crepicephalus* Zone.

Franklin Mountain Formation

At the type section (Williams, 1922, 1923), the Franklin Mountain Formation is composed of at least 280 m of dolostone that includes a basal rhythmic member (covered), a cyclic member, and a cherty member. Each member can be recognized over a wide area (Norford and Macqueen, 1975, p. 9-11). A regional disconformity separates the Franklin Mountain Formation from the overlying Mount Kindle Formation (op. cit.).

In the southeastern part of the map area (106F13), Norford (1964, Section 2, Units 1-11) recorded 510 m of Franklin Mountain Formation. In most of this part of the area, the Franklin Mountain is believed to unconformably overlie Precambrian strata. However, within a large thrust sheet centred at 65°02′30″N, 132°30′00″W, in the Mackenzie Mountains, it is bounded by different formations (Norris, 1982a). There, the Franklin Mountain Formation disconformably overlies the Lower Cambrian Sekwi Formation and grades laterally and upward into the Road River Formation.

Fossils collected from the Franklin Mountain Formation range in age from early Late Cambrian into Early Ordovician (Norford and Macqueen, 1975, p. 35, 36). The oldest fossil collection from south of the map area (Keele River), belongs to the *Cedaria-Crepicephalus* Zone. The collection is older (Dresbachian) than the sub-Franconian unconformity, recognized still farther south by Gabrielse et al. (1973). The common Franconian brachiopod *Billingsella* is known from collections in the Franklin Mountain Formation, one of these (GSC loc. 54064) being from the rhythmic member in the southeastern part of the map area (Norford and Macqueen, 1975, p. 36). It has been suggested (op. cit., p. 12) that the Cambrian–Ordovician boundary "may lie within the rhythmic unit, or between the rhythmic and the overlying cherty units".

The Franklin Mountain Formation correlates (Fig. 5.2) in part with the Taiga Formation (Dresbachian part) and in part with the unnamed carbonate unit (ЄDb, medial Upper Cambrian *Elvinia* Zone to Devonian), both of which are located in the Yukon Block. It also correlates with the Broken Skull and Rabbitkettle formations in the southern Mackenzie Mountains.

RICHARDSON TROUGH

General statement

The Richardson Trough acted as a negative physiographic feature from late Early Cambrian time until at least the end of the Devonian. During this time, clastics shed from the Mackenzie Platform were either trapped or diverted in the trough, and were thereby prevented from moving farther west onto the Yukon Block. The exceptionally pure carbonates on the Yukon Block, such as those in the Illtyd Formation, unnamed carbonate formation, and Jones Ridge Limestone in adjacent parts of Alaska, reflect the lack of terrigenous clastics.

During Middle Cambrian time, sands poured into the Richardson Trough from the west as a result of faulting on the Yukon Block. These sands also filled grabens on the block, and in both regions they have been assigned to the Slats Creek Formation. Southeast of the Richardson Trough, in the Selwyn Basin, similar and possibly related sandstones have been reported by Fritz (1976, Sections 1, 2) and Cecile (1982, Section 5). There, the sandstone unit overlies uppermost Lower Cambrian strata and contains exotic boulders that contain latest Early Cambrian fossils (Fritz, 1976, p. 8). No fossils have been found within the sandstone surrounding the boulders.

More typical of strata within the Richardson Trough and near its margins, are medium and dark coloured, thin bedded limestone and dark grey shale. Lower Cambrian strata of this type are locally replaced by thick bedded to massive, light coloured carbonate, some of which is in buildups (Fig. 5.3a, Section 3, Unit 4, 106M7; Fig. 5.3b, Section 6, Unit 4, 106E6; Fig. 5.3b, Section 8, Unit 5, 106E3; Fig. 5.3b, Section 9, Unit 3, 106E10). Although some of these strata are believed to have been deposited below wave base, there is little evidence of great depth or relief. Slump folds, penecontemporaneous slump breccia, and moderately deep-water trilobites, such as pagetiids and oryctocephalids, are lacking or rare.

Cambrian strata in the Richardson Trough have been divided into the following formations: uppermost Lower Cambrian Sekwi Formation, uppermost Lower Cambrian Illtyd Formation, uppermost Lower Cambrian and Middle Cambrian Slats Creek Formation, and uppermost Lower Cambrian to Devonian Road River Formation.

Sekwi Formation

The oldest Cambrian strata in or near the south end of the Richardson Trough belong to the Sekwi Formation. These strata are exposed in the southeastern part of the project area, where they have been thrust northward onto the craton from an intermediate position between the Mackenzie Platform and the Cordilleran Geocline. At one outcrop of these transported Sekwi strata (at 65°00′20″N, 132°34′00″W), the formation comprises interbeds of orange dolostone, sandstone and thin, wavy bedded limestone. At this locality the Sekwi probably belongs mainly, if not wholly, to the *Bonnia-Olenellus* Zone, whereas farther to the southeast the formation is known (Fritz, 1979) to range from the upper *Fallotaspis* Zone, through the *Nevadella* Zone, and into the *Bonnia-Olenellus* Zone.

Formations that correlate with the Sekwi Formation are the Rosella Formation (upper Atan Group) in the Cassiar Mountains (Fritz, 1980), and the combined uppermost McNaughton, Mural, Mahto and Hota formations of the Canadian Rocky Mountains (Fritz and Mountjoy, 1975). The Mount Clark Formation is the eastward equivalent of the upper part of the Sekwi Formation. The Mount Cap Formation is generally recognized as being lithologically distinct and younger than the Sekwi or Mount Clark formations, however Aitken et al. (1973) report areas where the Mount Cap extends down to the Precambrian-Cambrian unconformity at the expense of the Mount Clark. This upper Lower Cambrian part of the Mount Clark Formation is equivalent to the upper part of the Sekwi Formation.

Illtyd Formation

In the Richardson Trough the Illtyd Formation is Early Cambrian in age and unconformably overlies the Precambrian. There the Illtyd Formation both underlies and laterally interfingers with the Road River Formation (Fritz, 1985, Fig. 25.2). In other areas, where Slats Creek clastics have poured into the trough from the west, that formation directly overlies the Illtyd Formation (op. cit.).

Near the northern end of the Richardson Trough (Fig. 5.3a, Section 3, 106M7; Pl. 5.1, fig. 5) the Illtyd Formation (486.5 m) consists of a lower siltstone member (Unit 1) and a shale and interbedded limestone member with carbonate buildups at the top (Units 2–4). The light grey buildups and medium grey, wavy bedded limestone at the top of the Illtyd Formation serve to differentiate it from the more recessive, dark platy limestone and shale of the overlying Road River Formation.

Farther south in the trough, at Section 5 (Fig. 5.3a, 106L1; Pl. 5.2, fig. 2), the Illtyd Formation (440.5 m) comprises white, pelletoid limestone in medium to massive beds and interbedded medium grey limestone in thin, wavy beds. The latter limestone is finely crystalline or fine to coarse grained. The formation is abruptly overlain by the sandstone of the Slats Creek Formation.

In the most southerly Illtyd section in the trough (Pl. 5.3, fig. 4, Section 9, 106E10; 1085.5 m), the Illtyd is readily recognized by its interbedded units (Units 3, 4, 7, parts of 9, 10) of white carbonate. The remainder of the formation is mostly thin, wavy bedded limestone. In this area the Illtyd-Road River contact may be faulted, but it probably once resembled that at Section 3.

Road River Formation

The Lower Cambrian through Devonian Road River Formation is only briefly described here, with emphasis placed on the diachronous lower contact. A more thorough discussion is given in the next chapter on the Ordovician and Silurian rocks.

At Section 3, the basal Road River (271+ m) encircles carbonate buildups of the uppermost Illtyd Formation (Pl. 5.1, fig. 5). There, the lower Road River is comprised of dark, platy limestone and interbedded dark shale. The lower Road River Formation in Units 1 to 3 in Section 3 belongs to the upper third of the *Bonnia–Olenellus* Zone. Higher in the section, between Units 3 and 4, an unconformity may be present within the formation. Overlying the possible unconformity is chert-bearing, platy limestone that resembles Ordovician strata elsewhere in the Road River. Still higher in the section, the Road River Formation is disconformably overlain by Permian strata.

The Road River Formation at Section 4 (106L8; 152+ m) lies 9 km south of the type section. Jackson and Lenz (1962, p. 32) report that: "The lower boundary was not seen in the type section but is well exposed on the Road River and other localities in the Richardson Mountains, where a thick sequence of limestones generally present in the lower part of the formation is apparently conformably underlain by shale, siltstone, and sandstone of Cambrian Age". Section 4 is a reference section where I (Fritz, 1985, p. 209) formally proposed placing the base of the Road River Formation at the contact between the basal Road River black shale map unit (ЄDrO) and the underlying sandstone of the Slats Creek Formation. A short distance north of Section 4, the basal 41 m of the Road River is well exposed. There, black shale with abundant *Protospongia* sp. (GSC loc. 90525) comprises 90 per cent of the succession. Sparse interbedded sandstone, like that in the Slats Creek Formation, is present, along with rare, planar laminated limestone lenses. Float samples (GSC locs. 90526-90528), collected 41 to 80.5 m above the base of the formation, contain *Coosella*? sp., *Blountia*? sp. and *Deiracephalus* sp., of the Upper Cambrian *Cedaria–Crepicephalus* Zone.

It is likely that the covered Illtyd–Road River contact at Section 9 is also a fault contact. B.S. Norford (pers. comm., 1974) assigned graptolites collected a short distance above the boundary to the "Middle or Late Ordovician" (GSC loc. 89892) and to the "Middle Ordovician to Early Silurian" (GSC loc. 89893).

Slats Creek Formation

The largest area of exposure of the Slats Creek Formation lies in the middle of the Richardson Trough. At Section 4 (Fig. 5.4a; Pl. 5.2, fig. 1), near the northeast margin of this exposure, the Slats Creek Formation is represented by a monotonous succession of rusty to medium brown weathering sandstone that exceeds 747 m in thickness (base not exposed). The sandstone is in medium to thin beds that are medium to medium dark grey on fresh surfaces. The fine to very fine grain size throughout the section probably reflects a grain size achieved during an earlier depositional cycle, as it is the same grain size seen within quartzite pebbles and cobbles from the Slats Creek Formation near its source area on the Yukon Block (Pl. 5.2, fig. 6,). At Section 4, current generated features are very rare, and transport direction could not be ascertained.

At Section 5, near the southwest margin of the large exposure, sandstone similar to that in Section 4 comprises 20 per cent of the strata in the lower 132.5 m (higher strata not measured) of the Slats Creek Formation. The sandstone is in thin beds intercalated with dark grey to black siltstone and shale. Sponge spicules belonging to the genus *Protospongia* are present 33.5 m above the base of the Slats Creek succession.

YUKON BLOCK

General statement

Cambrian strata in this region are placed in the following formations (Fig. 2): upper Lower Cambrian Illtyd Formation, Middle (including minor uppermost Lower) Cambrian Slats Creek Formation, Middle and lower Upper Cambrian Taiga Formation, Upper Cambrian to Devonian unnamed carbonate formation (map unit ЄDb), and Upper Cambrian(?) through Silurian Vunta Formation. The Lower Cambrian to Middle Ordovician Jones Ridge Limestone within a thrust plate that straddles the southwest boundary of the map area (Yukon/Alaska border) is also included with the Yukon Block strata. The Jones Ridge strata represent the relatively thick, outermost (western) edge of the carbonate platform.

Illtyd Formation (including description of the type section)

The formation name is derived from Illtyd Creek, which has good exposures of Illtyd strata near its headwaters, at Sections 7 (106E19) and 8 (106E3; see also Pl. 5.3, figs. 1–3; Pl. 5.4, fig. 1; Fritz, 1974, fig. 2g). At a typical Illtyd outcrop the lower one fourth of the formation comprises interbedded siltstone, quartzite, and thin to medium bedded carbonate. These strata create moderately rugged topography. There is little change in topographic expression at the unconformity between the Illtyd Formation and the underlying Hadrynian or older Precambrian strata. At Section 8 the Illtyd is underlain by thin bedded maroon quartzite (Pl. 5.1, fig. 6) and at Section 7 it is underlain by bright orange, thin beds of finely laminated dolostone.

The upper three fourths of the formation typically comprises very light grey to white weathering carbonate in a series of massive cliffs separated by less resistant intervals containing thin and medium bedded limestone. The upper boundary of the Illtyd Formation is drawn at an abrupt topographic and lithologic break between resistant carbonate and the darker, recessive weathering clastics of the overlying Slats Creek or Road River formations.

Type section (Section 8, 106E3; 8946 m)

The type section of the Illtyd Formation (Fig. 5.3b) is centred at latitude 65°05′45″, longitude 134°42′30″, on a north-northeast trending ridge in the northeastern part of the Wernecke Mountains. There, the formation comprises a lower member (Units 1–4, 512 m) of siltstone with some interbedded sandstone and limestone, and an upper member (Units 5, 6, 434 m) composed of light coloured carbonate. The trilobites within the type section have been described (Fritz, 1991) together with a brief lithologic description, but a more detailed lithologic description is presented below.

The lowest unit (Unit 1, 76 m) comprises sandstone that is mainly light brown on weathered and fresh surfaces. Some maroon coloured sandstone is also present. The sandstone in the basal 23 m is thick bedded and fine to coarse grained, but it also contains some quartz clasts up to 3 mm in diameter. The remainder of the unit is medium to thick bedded and is very fine grained. The contact between Unit 1 and the underlying Precambrian strata is abrupt and angular. Below the contact are thin wavy beds of maroon-weathering quartzite that are maroon to purple on fresh surfaces. The Precambrian quartzite is very fine grained and locally dips 40° to the south. Above the contact, the sandstone in Unit 1 dips gently to the east (Pl. 5.3, fig. 2).

The second unit (Unit 2, 70.5 m) is composed of wavy and nodular beds of limestone that weather light brown (0–39.5 m) and medium orange-brown (39.5–70.5 m). The limestone is dark grey on fresh surfaces and is mainly finely crystalline, but a significant amount of bioclastic limestone is also present.

Light yellow-brown weathering shale predominates in Unit 3 (236.5 m). The shale is olive-grey and medium to dark grey on fresh surfaces and is silty at various levels. Thin to thick, blocky weathering, limestone beds occupy the intervals 49 to 52 m and 62.5 to 65.5 m above the base of the unit. The limestone weathers orange-brown and is finely to medium-crystalline. The interval 65.5 to 150 m above the base contains 50 per cent shale as described above, and 50 per cent medium grey to orange weathering, finely crystalline limestone in thin, wavy beds and nodules. Fresh limestone surfaces are dark grey. Some limy sandstone and siltstone beds are present in the upper one third (185–188 m, 202–216 m) of the unit. The sandstone is in thin to thick beds and is fine to very fine grained.

Unit 4 (129 m) comprises two subunits of quartz sandstone separated by a medial subunit of limestone. The basal subunit (44 m) contains medium orange-brown weathering, very fine grained sandstone in thin and medium, wavy beds. Fresh surfaces are medium grey. The medial subunit (39 m) is composed of medium blue-grey, finely crystalline limestone in thin, wavy beds. Fresh surfaces are medium dark grey. Thin beds of light brown weathering, very fine grained sandstone predominate in the upper subunit (46 m). The top 14.4 m of the upper subunit contains medium grained sandstone as well as layers of grit and pebbles (up to 2 cm in diameter).

Unit 5 (245.5 m) contains one of the numerous carbonate buildups within the unit. Another buildup is exposed 2.5 km to the west (Pl. 5.3, fig. 1). The lowest subunit (subunit 1, 26 m) consists of massive, cliff-forming, light grey pelletoidal limestone. The basal 3 m contains light pink, medium grained, bioclastic limestone. Subunit 2 (40.5 m) contains thin to medium beds of limestone. This limestone weathers light pink, medium blue-grey, and light grey. Subunit 3 (128.5 m) represents the core of a large buildup. It consists of thick to very thick bedded, finely to coarsely crystalline dolostone that weathers light grey and is grey to light brown on fresh surfaces. Vugs in the upper half of the subunit average 2.5 cm in diameter and the largest seen has a maximum measurement of 12 x 5 cm (length x width) in cross-section. The original carbonate in subunit 3 was probably the same as the limestone in subunit 1, because similar unaltered limestone of that type is exposed in patches that grade into the dolostone in the buildup core. Bright orange weathering dolostone in thick and medium beds predominate in the uppermost subunit (subunit 4, 50.5 m) of Unit 5. Freshly exposed surfaces are light grey to light brown and the dolostone is medium crystalline.

Unit 6 (188.5 m) comprises limestone in a recessive weathering lower subunit (89.5 m) and a resistant weathering, thick bedded to massive upper subunit (99 m). The limestone in the lower subunit is in wavy or irregular beds that are medium grey on weathered and fresh surfaces. It is finely crystalline and locally contains intraclasts averaging 4 mm in diameter. The limestone in the upper subunit is light grey on fresh and weathered surfaces and is microcrystalline to finely crystalline. Near the top (61 to 98 m above base of the subunit) the limestone is locally replaced by medium to thick bedded, light grey and light orange weathering dolostone. About 17.5 m of thin bedded limestone, similar to that in the lower subunit, is present in the upper subunit. At the top of Unit 6 and at the top of the Illtyd Formation is 1 m of medium grey weathering, finely crystalline limestone in thin, wavy beds. Abruptly overlying the limestone is a thick succession of medium grey siltstone belonging to the Slats Creek Formation.

In the Yukon Block, most of the Illtyd Formation was removed by Middle Cambrian, late Dresbachian (early Late Cambrian), and post-Cambrian erosion. However, enough data are present at widely separate Illtyd sections to provide insights into the formation's general history. A major erosional surface cuts into Hadrynian and older strata immediately below the formation's base, in the Yukon Block and the Richardson Trough. Unconformably above this surface, Illtyd strata are mainly composed of clay to fine sand grade clastics. The size range, widespread distribution, and limited thickness of these basal clastics indicate deposition over a surface of low relief. No negative movement of the Richardson Trough relative to the Yukon Block is evident in the lower Illtyd strata. Negative movement that did serve to differentiate the two regions is reflected in the middle and upper parts of the formation. Once started, the trough continued sinking relative to the Yukon Block and Mackenzie Platform throughout the remainder of the Cambrian and later.

At Section 1 (116P16; Pl. 5.1, figs. 1, 2), near the northeastern corner of the Yukon Block, the basal Illtyd units (Units 1-3) contain redbeds, *Skolithos* tubes and crossbeds, features that suggest deposition in a shallow marine environment. Elsewhere, shallow-water features are present in the lower part of the formation, but are less striking than at Section 1.

Two types of exceptionally clean carbonate rocks dominate the middle and upper part of the Illtyd Formation in the Yukon Block. Pelletoidal limestone in white, thick to massive, cliff-forming beds (Pl. 5.2, figs. 2, 3) is the most prominent of the two. The second type, alternating with the first, is thick intervals of light grey, thin to thick beds replete with locally derived fine to pebble sized carbonate clasts (Figs. 5.3a, b).

As mentioned previously, the upper contact of the Illtyd Formation is sharp where it is overlain by the clastics of the Slats Creek Formation. At Section 2 (116P7b), in the White Mountains, an unconformity probably separates the Illtyd from the overlying unnamed breccia unit. Below the unconformity(?) is a thick dolostone succession. Above it is a slightly less resistant succession of carbonate breccia (Fritz, 1974, fig. 2a) that is questionably assigned to the Upper Cambrian. At nearby Section 3 (106M7), and at the various other localities within the Richardson Trough, the Illtyd Formation is overlain by the Road River Formation. There, the upper Illtyd contact is drawn at the top of the highest, light coloured carbonate bed and below recessive, dark platy limestone and shale.

The Illtyd Formation belongs to the middle and upper *Bonnia-Olenellus* Zone. In the type section, the middle part of the zone is documented by the presence of the trilobites *Bonnia laterispina* Fritz, *Proliostracus ampliatus* Fritz, *Variopelta brevicervicata* Fritz, and *Wanneria logani* (Walcott), and by the index fossil *Salterella* (Fritz and Yochelson, 1988, p. 409). In the same section the upper part of the zone is indicated by *Antagmus ducketti* Fritz, *Bonnia fieldensis?* (Walcott), *Bonnia columbensis* Resser, *Syspacephalus werneckensis* Fritz, and *Zacanthopsis expansa* Fritz.

The Illtyd Formation at Sections 3, 5, 6, 7, and 9 also contains fossils of the middle and upper parts of the *Bonnia-Olenellus* Zone. Illtyd strata at Sections 1 and 2 are composed mainly of unfossiliferous dolostone. At Section 1, olenellids of the *Bonnia-Olenellus* Zone are present in the basal siltstone member (GSC loc. 90501), but their position within the zone is uncertain. Archaeocyathids(?) from near the base of the upper carbonate member in Section 2 (Fritz, 1974, fig. 2b) suggest placement within the medial *Bonnia-Olenellus* Zone because elsewhere in the Cordillera archaeocyathids are not found in younger strata.

The upper part of the Illtyd Formation correlates with the Mount Clark Formation and the lower part of the Mount Cap Formation in areas where the latter formation locally displaces the former (Fig. 5.2). The main development of the Illtyd Formation locally correlates with the Sekwi Formation with which it interfingers in the southern part of the Richardson Trough, and with the upper half of the expanded Sekwi Formation farther south in the Mackenzie Mountains (Fritz, 1979). Like the Sekwi Formation, the Illtyd has an upper contact that is diachronous with the overlying Road River Formation (Fritz, 1985).

The lithology, overlapping age, and its position on or near the Yukon Block suggests the Illtyd Formation may have been part of the Jones Ridge Formation before the two were separated by post-depositional erosion (Fritz, 1974, fig. 3). Jones Ridge deposition on the southwestern edge of the Yukon Block began earlier than Illtyd deposition on the eastern edge of the block did, as indicated by the presence of archaeocyathids in the lower portion of that formation. Illtyd deposition terminated with the influx of Middle Cambrian Slats Creek clastics, whereas the white carbonate of the Jones Ridge is reported to range into the Ordovican (Brabb, 1967). However, no Middle Cambrian fossils are known to come from the Jones Ridge limestone; in nearby slope deposits of the Hillard Formation all of the Middle Cambrian is missing except for the *Bolaspidella* Zone (Palmer, 1968).

In the British–Barn Trough, a highly folded and faulted argillite unit, estimated to be 200 to 500 m thick in the Barn Mountains (Cecile, 1988), probably correlates, at least in part, with the Illtyd Formation. The unit contains *Oldhamia* and is overlain by an Ordovician siliceous argillite and chert unit (op. cit.). The Cambrian argillites, again containing *Oldhamia*, are reported to be below the Ordovician chert-bearing unit in the same basin, near Firth River 80 km northwest (Lane and Cecile, 1989), and near the Yukon/Alaska border farther northwest (Lane et al., 1991). Near Firth River the Cambrian argillites are either underlain or in part laterally displaced by quartzite.

Slats Creek Formation (including description of the type section)

This formation is named for a creek located 33 km southeast of the type section (Fig. 5.4b, Section 7, 106E19) and 13 km southeast of Section 8 (106E3a). The formation is exposed in the Ogilvie Mountains, Wernecke Mountains (Fig. 5.4b, Sections 7, 8), Taiga Range, Illtyd Range (Section 6), and in the Richardson Mountains (Fig. 5.4a, Sections 4, 5). A significant angular unconformity is present at the base of the formation in the Ogilvie and western Wernecke Mountains, where the formation rests on Precambrian strata. In the eastern Wernecke Mountains, Illtyd Range and Richardson Mountains, the formation overlies latest Lower Cambrian strata (Illtyd Formation).

Although I have not seen the Slats Creek Formation to the west, I assume that the basal contact there is like that in the east.

In the east, the Slats Creek–Illtyd contact is sharp at Sections 5, 6 and 8 (Figs. 5.4a, b). There the Illtyd carbonates are abruptly overlain by a continuous succession of fine grained Slats Creek sandstone. The lower contact at the type section (Section 7) is more complex, and is discussed later in the text.

The upper Slats Creek contact in the central Richardson Mountains (Fig. 5.4a, Section 4, 106L8) is covered, but float and nearby outcrops to the north confirm that it lies at the top of a succession of very fine grained, light brown sandstone that is immediately overlain by recessive weathering, black shale of the Road River Formation. In the Illtyd Range (Fig. 5.4b, Section 6; Pl. 5.2, fig. 5; 106E6) the upper contact is located at an abrupt lithological change between Slats Creek conglomerate and clean, light coloured limestone of the overlying unnamed Upper Cambrian to Devonian carbonate formation (map unit ЄDb). This contact is an unconformity, representing the removal of the Taiga Formation and probably part of the upper Slats Creek Formation. To the south, in the eastern Wernecke Mountains (Fig. 5.4b, Sections 7, 8), this contact is drawn at the horizon where the predominantly clastic succession of the Slats Creek give way to the predominantly carbonate succession of the Taiga Formation. From a distance (Pl. 5.3, fig. 1) this contact can be easily drawn; the light coloured Taiga carbonates bear little resemblance to the underlying darker Slats Creek clastics. The depositional contact between the Slats Creek and Taiga formations in nearby Section 7 is absent because of faulting. I have not seen the upper or lower Taiga contact in the Taiga Range.

The Slats Creek Formation is recessive, relative to the underlying Illtyd Formation and the overlying Taiga or unnamed carbonate formations. Where overlain by the Road River Formation, the Slats Creek is slightly more competent but the contact is best placed using lithological (usually float) rather than physiographic control.

Type section (Section 7, 106E19, 1572 m)

At the type section (Fig. 5.4b, Section 7; Pl. 5.4, figs. 1-3) the Slats Creek Formation comprises a lower siltstone member (Units 1-4, 799 m) and an upper conglomerate and sandstone member (Units 5-7; 772.5 m).

Unit 1 (44.5 m) in the Slats Creek Formation is composed of thin bedded, very fine to fine grained sandstone. In the intervals 0 to 14.5 m and 43 to 44.5 m the sandstone is brownish grey weathering and is medium dark grey on fresh surfaces, and between 14.5 and 35.5 m the sandstone weathers orange-brown and is medium greenish grey on fresh surfaces. The interval 35.5 to 43 m contains medium grey weathering siltstone.

Unit 2 (196 m) comprises maroon-grey and purple-grey weathering siltstone and very fine grained sandstone. The strata contain very thin laminae. Sparse trace fossils are present at various horizons and are abundant near the top. The interval 37 to 44 m above the base contains some sandstone that ranges up to coarse grained and some beds containing clasts of siltstone.

Although thin (22 m), Unit 3 is prominent in the lower member because it contains limestone that is sparse or absent elsewhere. The limestone is medium grey and in thin, wavy beds. Also present are some greenish grey, argillaceous limestone and light brown, bioclastic limestone. Limestone mounds 1 m high are exposed near the centre of the unit.

A thick (536.5 m) succession of slightly limy siltstone that is maroon-grey in the lower part (0-324.6 m) and brownish grey in the upper part (324.5-536.5 m) comprises Unit 4. Thin interbeds of very fine grained sandstone containing trace fossils are also present in the basal 52 m of the unit. The interval 399.5 to 406 m contains medium grey weathering, coarse grained limestone in thin, wavy beds and some interbedded, very fine grained sandstone. In the uppermost 8.5 m of the unit, some (20%) orange weathering, very fine grained sandstone is present in thin beds that terminate against a small(?) fault which separates Unit 4 from a conglomerate bed at the base of Unit 5.

Unit 5 (251.5 m) comprises light brown to light yellowish grey weathering, very fine and fine grained sandstone. The bedding is thin to thick with a general upward increase in bedding thickness. Conglomerate is present in the intervals 0 to 5 m, 91.5 to 92 m, and 201.5 to 206 m above the base of the unit. Some interbeds of brick-red weathering siltstone are present at various intervals, starting 78.5 m below the top of the unit and continuing into overlying Unit 6. Since the thickest continuous succession of the redbeds is 10 m thick, it cannot be confused with the much thicker succession of redbeds in Unit 7.

Unit 6 (152 m) contains conglomerate in thick to massive beds. In the lower part, the conglomerate is interbedded with 20 per cent brick-red or buff weathering siltstone and very fine grained sandstone. Generally, the conglomerate beds weather light brownish grey, and the most common pebbles and boulders are composed of very fine to fine grained quartzites that weather light maroon, light grey, and light brown. Some clasts of light grey dolostone are also present. A conglomerate bed located 56 m above the base of the subunit has been previously illustrated (Fritz, 1974, fig. 2f), and a bed similar to those in the type section, but located in Section 6, is illustrated in Plate 5.2, figure 6.

Unit 7 (369 m) is composed of thin, platy beds of siltstone and very fine grained sandstone that is brick red on both weathered and fresh surfaces.

Olenellus sp. is present 77 m above the base of the Slats Creek Formation (GSC loc. 90620) in Section 7, and therefore the formation, up to at least that level, belongs in the Lower Cambrian *Bonnia-Olenellus* Zone. The boundary between the Lower and Middle Cambrian is tentatively placed 4.5 m higher, at the base of a 7 m sandstone succession (Fig. 5.4b). Other fossils found in the formation belong to the *Plagiura-Poliella* and/or *Albertella* Zone (GSC locs. 90621-90626), questionably to the *Glossopleura* Zone (GSC locs. 90627-90629), and definitely to the *Glossopleura* Zone (GSC locs. 90630-90636). The base of the Slats Creek Formation is considered diachronous between Sections 7 and 8, because at Section 8 the basal Slats Creek belongs to the Middle Cambrian *Plagiura-Poliella* Zone (GSC locs. 90675-90678). The presence of *Glossopleura* within the Slats Creek Formation and of cf. *Polypleuraspis* sp. (GSC loc. 90682) in the overlying Taiga Formation at Section 8 indicates that here the Slats Creek-Taiga boundary is within the *Glossopleura* Zone.

No fossils were found in the Slats Creek Formation at Sections 4, 5 and 6, except for the long ranging sponge *Protospongia* sp. at Section 5. At two and probably all three of these sections, the Slats Creek is underlain by the Lower Cambrian Illtyd Formation. As mentioned previously, the Slats Creek Formation at Section 5 is immediately overlain by dark shale that contains *Protopsongia* and fossils belonging to the *Cedaria-Crepicephalus* Zone (GSC locs. 90526-90528), 41 to 80.5 m above the top of the formation.

A variable lithology, including redbeds and conglomerates, and rapid changes in thickness of the Slats Creek Formation suggest deposition in grabens within the Yukon Block, and the shedding of excess clastics into the Richardson Trough. Block faulting is also suggested by the isolated outcrops of the Slats Creek in the Wernecke Mountains west of the measured sections (Norris, 1982b; Forest Fault), where the formation unconformably overlies Precambrian strata and has a paraconformable contact with overlying formations. Green (1972, p. 28) has postulated that block faulting occurred in the Wernecke Mountains, immediately south of the map area, after the deposition of strata (op. cit., Units 5, 6) that are here referred to as the Slats Creek and Taiga formations, but before deposition of the unnamed carbonate formation (op. cit., Unit 8). However, it is far more likely that block faulting took place during deposition of the Slats Creek. Green states (op. cit., p. 24) that Unit 5 (Slats Creek) "... is best exposed in Nash Creek map-area, where it may exceed 3500 feet (1070 m) in thickness and consists of conglomerate, sandstone, and siltstone with interbedded flows. Elsewhere the unit is seldom more than a few hundred feet thick and sandstone is the dominant lithology...."

The Slats Creek Formation correlates with the Mount Cap Formation on the Mackenzie Platform. The interfingering of Slats Creek sandstone with Road River shale in the Richardson Trough (Section 5, 106L1) indicates that part of the latter formation is equivalent in age to the Slats Creek. However, early Middle Cambrian fossils have yet to be collected from the Road River Formation in the trough.

To the south, in the Selwyn Basin, the lower part of the Hess River Formation (the lowest formation in the Road River Group; Cecile, 1982) is probably the same age as the Slats Creek Formation. The earlier mentioned correlation between the Slats Creek Formation and Unit 5 of Green (1972) is based upon lithological similarities, and Unit 5's position above a regional unconformity and below carbonates (Unit 6 of Green, 1972) bearing a *Cedaria-Crepicephalus* fauna.

Correlation of the Slats Creek Formation to strata within the Jones Ridge Formation is uncertain. The Jones Ridge and laterally adjacent Hillard Limestone contain fossils that pre- and postdate the early Middle Cambrian (Palmer, 1968, p. 8), but none that correlate with fossils in the Slats Creek. It is assumed that the Slats Creek Formation correlates with part of the Cambrian in the British-Barn Trough exposed in the Barn Mountains (Cecile, 1988), near Firth River (Lane and Cecile, 1989), and near the Yukon/Alaska border (Lane et al., 1991), but Middle Cambrian fossils have yet to be found in those areas.

Taiga Formation (including description of the type section)

General Statement

This formation is named after the Taiga Range, where the map unit is extensively exposed. Section 7 (Fig. 5.4b, 106E19) in the Wernecke Mountains is designated as the type section. Good exposures of the lower member are also present in the same mountains at Section 8 (Fig. 5.4b). At the type section, the formation starts above a faulted base and contains a lower, orange weathering, dolostone member (Units 1, 2; 361+ m) and an upper, medium to light grey, limestone member (Units 3, 4; 223 m). At Section 8, the lower member includes abundant light brownish grey weathering dolostone.

The Taiga Formation is more resistant to weathering than the underlying Slats Creek Formation, but less than the overlying unnamed carbonate formation (Pl. 5.4, fig. 3). Variable bedding thickness, interbedding of clastics and carbonates that accentuates parting, and contrasting weathering colours among beds in a given outcrop combine to produce a striped appearance. This is in marked contrast to the monotonous, thick bedded strata in the overlying unnamed carbonate formation.

In the Illtyd Range, strata immediately underlying the unnamed carbonate unit could be mistaken for the Taiga Formation, because of their intermediate resistance to weathering and orange weathering colour. However, the appearance of these strata is attributed to a "pseudo-breccia" that laterally grades into clean carbonates similar to those in the formation above. These pseudo-breccias lack the striped appearance, interbedded shale and "floating" or bedded quartz sand and pebble-size clasts that are in the Taiga Formation.

The base of the Taiga Formation at Section 8 (Pl. 5.3, fig. 1) is at the base of a thick dolostone succession that weathers light brownish grey to orange-grey. Below the basal contact is Slats Creek siltstone that weathers light grey, light brown, orange and maroon. I have not seen the base of the Taiga elsewhere.

The top of the formation at the type section is a sharp contact. Below is medium grey weathering, thin to thick bedded, Taiga limestone, and above is light to medium grey weathering, thin to medium bedded dolostone of an unnamed formation. The contact is believed to be an erosional surface of moderate local relief, but which cuts much deeper in the nearby Illtyd Range where the Taiga and upper part of the Slats

Creek Formation have been removed. At Section 8 the upper Taiga contact is at the top of a cream and orange-cream weathering succession of medium bedded dolostone. Above the contact is light grey weathering, thick bedded to massive pelletoidal limestone of the unnamed carbonate formation (€Db). I have seen the upper Taiga contact only at Sections 7 and 8.

Type section (Fig. 5.4b, Section 7, 106E19, 584+ m)

The lowest unit (Unit 1, 137+ m) in the type section comprises bright orange weathering dolostone and light grey weathering limestone, both of which occur as thick blocky beds. Both kinds of carbonate are light grey on fresh surfaces and are finely crystalline. The limestone contains abundant oncholites (*Girvanella*?). Some beds of quartzite conglomerate with clasts up to 10 cm in diameter are present, and some beds of sandy dolostone are also present. Rare interbeds of maroon weathering, platy siltstone also were noted.

Bright (0–79 m) to dull (79–224 m) light orange weathering, finely crystalline dolostone in thin to thick beds characterizes Unit 2. Fresh dolostone surfaces are light grey. The dolostone in interval 79 to 132.5 m contains abundant quartz sand in horizontal and crossbedded laminae. The quartz sand is fine to coarse grained and a few rare clasts are as large as 12 mm in diameter. Sparse dolomitic sandstone beds are present elsewhere in the unit, such as a 2 m bed of fine grained sandstone 169 m above the base.

Unit 3 (139 m) comprises limestone and orange weathering dolomitic limestone and dolostone. Intervals 0 to 6 m and 24.5 to 80 m contain medium grey weathering limestone in thick to very thick beds (60%), and thin, wavy beds (40%). The rocks are medium to dark grey on fresh surfaces and are finely crystalline. The remaining strata in the unit are in rhythmic successions, each rhythm beginning with a thick bed of limestone as just described, but having an orange mottling near the top. The next component in the rhythm is a thick bed of orange weathering dolomitic limestone, which in turn is overlain by light yellow-grey, argillaceous limestone in thin (6 mm) plates. The thick bedded carbonate is medium to dark grey on fresh surfaces, and the platy limestone is light grey on fresh surfaces.

The uppermost unit (Unit 4, 84 m) comprises medium grey weathering, finely crystalline limestone that is medium grey on fresh surfaces and occurs in thick beds (60%) and thin, wavy beds (40%). The limestone closely resembles that in intervals 0 to 6 m and 24.5 to 80 m in Unit 3. The top of the Taiga Formation is in sharp contact with 67.5 m of light grey weathering, thin to thick bedded dolostone, which in turn is in contact with light grey to light brownish grey dolostone in mainly thick beds (67.5–700 m). Both of these overlying dolostones belong to the lower part of the unnamed carbonate formation.

All of the fossils from the type section of the Taiga Formation (GSC locs. 90637–90647) are from the upper one third of the formation, and they all belong to the Upper Cambrian *Cedaria-Crepicephalus* Zone. At Section 8, the Middle Cambrian trilobite cf. *Polypleuraspis* sp. was collected 135.5 m above the base of the formation (GSC loc. 90682). Since this fossil and those in the upper part of the underlying Slats Creek Formation belong to the *Glossopleura* Zone, that zone straddles the Taiga–Slats Creek contact at Section 8.

South of the map area, but still within the Wernecke Mountains, Green (1972, p. 29) reported the presence of *Cedaria-Crepicephalus* Zone fossils from undesignated horizons in his Unit 6. The close proximity, similar lithology and equivalent fossils suggest that the Taiga Formation can be extended southward to include Green's (1972) Unit 6. No pre-*Cedaria-Crepicephalus* Zone fossils have been reported from Unit 6, but Green (1972, p. 28) did mention that a transitional contact exists between his Unit 6 (Taiga Formation) and underlying Unit 5 (Slats Creek Formation).

On the Mackenzie Platform, several formations at least partially correlate with the Taiga Formation. The upper part of the Mount Cap Formation contains fossils belonging to the *Glossopleura* Zone, and the lower part of the Franklin Mountain Formation includes fossils belonging to the *Cedaria-Crepicephalus* Zone (Aitken et al., 1973). The exact age of the intervening Saline River Formation (barren) and the extent of sub-Saline River erosion is unknown, but the Saline River strata obviously fall within the age range of the Taiga Formation.

No diagnostic Middle Cambrian fossils have been reported from the Road River Formation in the Richardson Trough but, as mentioned earlier, the interfingering of Slats Creek and Road River strata indicate that early Middle Cambrian Road River strata are present, and it is likely that late Middle Cambrian Road River strata are also present. *Cedaria-Crepicephalus* Zone fossils in the Road River Formation are documented at Section 4 (GSC locs. 90625–90627).

The Taiga Formation correlates with a small part of the Jones Ridge Formation and the laterally adjacent

Hillard Formation. The latter formation contains fossils of late Middle Cambrian age and both formations contain fossils belonging to the *Cedaria-Crepicephalus* Zone (Palmer, 1968). Correlative strata may also be present in the unnamed carbonate and volcanic map unit (Ꞓwmv) in the British-Barn Trough (Norris, 1981). Thus far this map unit has produced only fossils that post- and predate the Taiga Formation (Dutro et al., 1972).

Unnamed Carbonate Formation (map unit ꞒDb)

This thick bedded, light grey carbonate formation is in part Late Cambrian in age, but contains mainly Ordovician through Lower Devonian strata, and therefore will be discussed in more detail in the following chapter.

At the base of the formation in the eastern Wernecke Mountains is a previously mentioned unconformity separating it from the underlying Taiga Formation. In the Illtyd Range the unconformity has eroded deeper. There the Taiga Formation is missing, as is part of the Slats Creek Formation. The lower 54 m of the unnamed carbonate weathers in part to a "pseudo breccia" (Pl. 5.2, fig. 4) that laterally interfingers with thick bedded, light grey limestone. The "clasts" in the "pseudo breccia" are of the same light grey limestone that is present in the surrounding unaltered beds. The "pseudo-breccia" matrix is a yellow-orange weathering carbonate. No definitive evidence could be found to indicate that the "pseudo breccia" is due to either collapse or infilling of cavities.

In the Illtyd Range, *Elvinia* Zone fossils (middle Upper Cambrian) are present in the lower part of the unnamed carbonate (GSC locs. 90607, 90608), and Lower Ordovician fossils are present in the interval 546 to 568.5 m above the base (GSC loc. 90609). Correlations for the unnamed carbonate unit are given in the following chapter.

Carbonate Breccia Unit

In the White Mountains (Pl. 5.1, figs. 3, 4; Fig. 5.4a, Section 2) a 110+ m thick carbonate breccia unit immediately overlies the Illtyd Formation and underlies the type section for the Vunta Formation (Norford 1964, p. 10, 116). The unit is composed of angular to rounded carbonate fragments (Fritz, 1974, fig. 2a). Norford (1964, p. 116) described the breccia unit as consisting mostly of dolostone that weathers to light shades of brown, pink, orange, and grey, and is finely to coarsely crystalline. Unmentioned, but also present, are fragments of light grey, pelletoidal limestone. North (1971, p. 313) speculated that the breccia may be a collapse breccia resulting from evaporite solution.

Vunta Formation

Outcrops of this formation are restricted to a small area in the White Mountains (Norford, 1964, p. 10) where Vunta strata overlie the carbonate breccia unit (Fig. 5.4a, Section 2, 116P7b). Norford (1964) described the type Vunta section (870 m) as a uniform succession of light grey, thick bedded, pelletoidal limestone, and has dated the formation as Cambrian or Ordovician through Silurian in age. Norford's lowest datable fossil locality, which he (1964, p. 10) assigned to the Lower Ordovician(?), is 395 m above the base of the Vunta Formation. The age and lithology of the Vunta suggest a close correlation between it and the unnamed carbonate formation.

Jones Ridge Limestone

This formation, together with the underlying Hadrynian upper Tindir Group, is exposed in thrust plates that lie astride the southwestern boundary of the map area. At the type section (Brabb, 1967, p. 15) the lower member of the formation (896 m) comprises clean, white, thick bedded to massive carbonate (Pl. 5.4, fig. 5) that ranges in age from Early Cambrian into Early Ordovician. The upper member (18 m) comprises yellow-brown bioclastic limestone of Middle and/or Late Ordovician age (Brabb, 1967, p. 19).

Underlying the Jones Ridge Formation is a dark coloured, platy limestone unit assigned to Unit A of the Tindir Group (Mertie, 1933, p. 370). Lithologic correlations to the Cambrian sections in the northern Yukon and Mackenzie Mountains, plus the lack of trace fossils in Unit A, suggest that the Jones Ridge-Unit A contact is an erosional surface, and that part of the Lower Cambrian and Upper Precambrian are missing. Overlying the Jones Ridge Formation are Upper Ordovician, dark coloured chert and shale that have been questionably assigned (Brabb, 1967, p. 19) to the Road River Formation.

Strata equivalent to the Jones Ridge Formation, which lie a short distance to the west of the main Jones Ridge outcrop, have been divided into three formations (Brabb, 1967). The lowest is the unfossiliferous Funnel Creek Formation (15-396 m), composed of very light coloured limestone similar to the limestone in the Jones Ridge Formation.

The Funnel Creek Formation is overlain by the Lower Cambrian Adams Argillite (90-200 m), comprised of grey, green and red argillite and shale. The Adams Argillite is in turn overlain by the Lower Cambrian to Ordovician Hillard Limestone (30–150 m) that contains penecontemporaneous breccia and platy limestone (Pl. 5.4, fig. 4). This latter formation suggests deposition on an unstable slope, immediately west of the Jones Ridge platform deposits.

The lack of Middle Cambrian fossils from the Jones Ridge Formation, except for those of the *Bolaspidella* Zone (Palmer, 1968, p. 8), plus evidence of Middle Cambrian erosion elsewhere on the Yukon Block, suggest that strata of this age may be missing in the Jones Ridge succession. Despite the probability that lowermost Lower Cambrian strata are missing at the base of the Jones Ridge, and that a Middle Cambrian erosional horizon may be present, this single formation contains strata correlative with most of the Cambrian formations on the Yukon Block and in other regions of the northern Yukon as well (Fig. 5.4). The close proximity, lithologic similarity and age suggest the Illtyd Formation may have been an eastward extending "tongue" of the Jones Ridge that was later isolated by erosion.

BRITISH–BARN TROUGH

Unnamed volcanic (Ꞓwmv) *and argillite unit* (Ꞓwma)

In the British Mountains, two informal map units (Ꞓwmv, Ꞓwma) have been assigned by Norris (1976, p. 457) to the Cambrian. The upper (volcanic) unit, comprising agglomerate, limestone and mafic flows, can be traced across the border into Alaska, where it contains Lower and Upper Cambrian trilobites (Palmer *in* Dutro et al., 1972). The lower unit (150 m) is composed of dark grey argillite and, in Canada, is considered to lie unconformably above a unit of the Proterozoic(?) Neruokpuk Formation (Norris, 1976, p. 457).

Neruokpuk Formation

Reiser et al. (1980) demonstrated that there was a far greater thickness of strata in four intermediate units between the volcanic unit and a restricted Neruokpuk Formation than previously believed. In Alaska, the Neruokpuk Formation was mapped to include mainly strata that closely conformed to the metamorphosed quartzites originally described in the Alaskan Neruokpuk type area (Leffingwell, 1919). In descending order (except for 1 and 2) the four intermediate units were: 1) a dark grey phyllite unit (less than 1300 m); 2) a sandstone unit (50 m) that locally intertongues with Unit 1; 3) an echinoderm debris-bearing, partly calcareous siltstone and sandstone unit (700–1300 m); and 4) a chert and phyllite unit (less than 100 m). The Precambrian–Cambrian boundary in Alaska was placed at an unconformity between the chert and phyllite unit (Unit 4) and the underlying restricted Neruokpuk Formation (Reiser et al., 1980).

The above remarks give only a broad outline from early reconnaissance results. The level of the Upper Cambrian and upper Lower Cambrian fossil localities in the volcanic unit is uncertain, and there is no information on Middle Cambrian fossils. It is likely that the Lower Cambrian Waucoban Series extends downward at the Lower Cambrian fossil locality, into at least the echinoderm debris-bearing calcareous siltstone and sandstone unit in Alaska. The thickness or absence of the underlying Lower Cambrian Placentian Series has yet to be rigorously investigated. A comparison of the Alaskan and Canadian maps indicates that nomenclatural problems still exist (Lane, 1991).

In northeastern Alaska and northwestern Yukon, the above described Cambrian in the British Mountains is absent to the south, possibly as far south as the Kaltag Fault, below a sub-Carboniferous erosion surface.

Undifferentiated quartzite and basinal argillite

Recent reconnaissance mapping in three areas in the British–Barn Trough has revealed a Lower Cambrian succession that resembles strata of the same age in the Selwyn Basin. The northernmost of these areas is centred in the northern part of the British Mountains at the intersection of the Yukon/Alaska border and latitude 69°26″ (Lane et al., 1991), the second is in the Buckland Hills (Lane and Cecile, 1989), and the third is in the Barn Mountains (Cecile, 1988). In each of these areas, and in the Selwyn Basin (Hofmann and Cecile, 1981), the Lower Cambrian(?) trace fossil *Oldhamia* is present in maroon and green argillites. The argillites in all four areas are overlain by basinal shale containing chert and Ordovician graptolites. These strata are in turn overlain by argillites containing Silurian graptolites, except in the Barn Mountains, where only older strata and the graptolite-bearing strata are nearby. Strata older than the *Oldhamia*-bearing argillites are not exposed in the Barn Mountains. In the other three areas, quartzite and some limestone are present below the *Oldhamia*-bearing argillites, but the relationship between these older strata and the beds above is unclear, in part due to intense deformation and perhaps also because of lateral facies changes. In all four areas, intense lateral movement has taken place, resulting in the repetition of beds. This observation, plus the general sparsity of fossils, suggest that delineating and understanding Cambrian strata in the British-Barn Trough will be a slow and difficult process.

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Appendix 5.1

Fossil identifications

GSC loc.	Identification	Distance above base of formation (m)
	Section 1	
90501	*Fremontella* sp. *Olenellus clarki* (Resser) *Olenellus nevadensis* (Walcott)	104.5
	Section 3	
90509	*Olenellus* sp. *Proliostracus* sp. fragment with *Wanneria*-like pattern	150.5
90510	*Olenellus* sp.	161
90511	*Bonnia laterispina*? Fritz	223
90512	*Bonnia* sp.	279.5
90513	*Bonnia* sp. *Olenellus* sp. *Paterina* sp.	383.5
90514	*Olenellus gilberti*? Meek	396
	ROAD RIVER FORMATION	
90515	*Bonnia* sp.	35.5
90516	*Olenellus*?	54
90517	*Olenellus puertoblancoensis* (Lochman)	66
90518	*Piaziella* sp.	69
90519	*Olenellus* sp.	86
90520	*Bonnia* sp. *Olenellus puertoblancoensis* (Lochman)	93.5
90521	*Olenellus*? sp.	134.5
90522	*Olenellus puertoblancoensis*? (Lochman) *Zacanthopsis*? sp.	165
90523	*Bonnia* sp.	207.5
	Section 4	
90525	*Protospongia* sp.	11
90526	*Coosella*? sp.	41
90527	unidentified trilobite	61
90528	*Blountia*? sp. *Deiracephalus* sp.	80.5
	ILLTYD FORMATION	
	Section 5	
90529	*Bonnia*? sp.	0.5
90530	collection lost	34.5
90531	*Bonnia* sp. *Wanneria*? sp.	50.5
90532	*Antagmus* sp. *Bonnia columbensis*? Resser *Olenellus* sp. *Onchocephalus* sp.	135.5
90533	*Olenellus* cf. *O. thompsoni* (Hall, 1859)	206.5
90534	*Bonnima* sp. Rasetti, 1948 *Helcionella*? sp. *Nisusia* sp. *Olenellus* sp. *Onchocephalus* sp.	233
90535	*Bonnima* sp. *Piaziella*? sp.	245.5
90536	*Bonnima* sp.	269.5
90537	*Bonnia* cf. *B. brennus* (Walcott)	303
90538	*Hyolithes* sp. *Nisusia*? sp. olenellid fragments	346
90539	*Bonnia* sp. *Poulsenia*? sp. *Zacanthopsis* sp.	424.5
90540	*Bonnia* sp. *Poulsenia*? sp. olenellid? fragment	434.5
90541	*Bonnima* sp. *Poulsenia*? sp.	440.5

SLATS CREEK FORMATION

GSC loc.	Identification	Distance above base of formation (m)
90542	*Protospongia* sp.	33.3

ILLTYD FORMATION (lowest exposure)

Section 6

GSC loc.	Identification	Distance above base of formation (m)
90597	*Olenellus*? sp.	1
90598	*Bonnia* sp. *Salterella* sp. *Wanneria parvifrons* Fritz	62
90599	*Wanneria logani* (Walcott) *Zacanthopsis* sp.	145.5
90600	*Bonnia* sp.	175
90601	*Bonnia* cf. *B. fieldensis* (Walcott)	305.5
90602	*Onchocephalus* sp.	307
90603	*Onchocephalus* sp.	402.5
90604	*Bonnia* sp. *Onchocephalus* sp. *Zacanthoprsis* sp.	
90605	*Bonnia* sp.	561.5
90606	*Bonnia* sp.	570

unnamed carbonate unit

GSC loc.	Identification	Distance above base of formation (m)
90607	*Buttsia* sp. *Iddingsia*? sp.	9.5
90608	*Buttsia* sp.	27.5
90609	*Leiostegium* sp. (identified by W.T. Dean) *Illaenus* sp.	564–569

ILLTYD FORMATION

Section 7

GSC loc.	Identification	Distance above base of formation (m)
90610	coleoid *Olenellus* sp.	51.5
90611	*Olenellus laxoculus*? Fritz	58
90612	*Olenellus laxoculus* Fritz *Proliostracus contractus* Fritz	68.5
90613	*Proliostracus* sp.	127
90614	*Bonnia* sp. (2 pairs of spines) *Helcionella* sp. *Olenellus* sp. *Wanneria*? sp.	196.5
90615	*Bonnia* sp. *Paterina* sp. *Somberella*? sp.	227
90616	*Olenellus* sp. *Paterina* sp.	281.5
90617	*Bonnia* sp. *Onchocephalus* sp.	302
90618	*Olenellus* sp.	328
90619	*Olenellus* sp. *Onchocephalus* sp.	363.5

SLATS CREEK FORMATION

GSC loc.	Identification	Distance above base of formation (m)
90620	*Olenellus* sp.	77
90621	*Nyella*? sp. *Coreospira*? sp. *Micromitra* sp. *Olenoides*? sp. *Ptarmiganoides*? sp.	245
90622	*Kochina* sp. *Micromitra* sp. monoplacophoran? *Ptarmiganoides*? sp.	260
90623	*Kochina* sp.	273
90624	*Poliella* sp.	302.5
90625	*Poliella* sp.	308.5
90626	cf. *Nyella clinolimbata* (Fritz)	312
90627	cf. *Albertellina* sp.	362
90628	*Alokistocare* sp.	467
90629	*Pachyaspis* sp.	500
90630	*Amecephalus* sp.	671
90631	*Gossopleura* sp. *Wimanella*? sp.	683.5
90632	*Glossopleura* sp.	689.5
90633	*Glossopleura* sp.	732
90634	*Glossopleura* sp.	782.5

GSC loc.	Identification	Distance above base of formation (m)
90635	*Glossopleura* sp.	848.5
90636	*Glossopleura* sp.	868

TAIGA FORMATION

GSC loc.	Identification	Distance above base of formation (m)
90637	*Bolaspidella*? sp. *Talbotina* *Tricrepicephalus*? sp.	340.5
90638	*Hyolithes* sp. *Talbotina* sp.	385.5
90639	*Genevievella* sp.	399
90640	*Lonchocephalus*? sp. *Talbotina* sp.	415.5
90641	*Genevievella* sp.	434.5
90642	*Cedaria*? sp. *Talbotina* sp.	446.5
90643	*Coosella*? sp. *Genevievella* sp. *Llanoaspis*? sp.	523.5
90644	*Kormagnostus* sp. aff. *Glyptometopus* sp. *Talbotina*? sp.	532
90645	cf. *Cedaria* sp.	542
90646	*Deiracephalus* sp. *Lonchocephalus* sp.	564
90647	*Densonella* sp. *Coosella*? sp. *Meteoraspis* sp.	578

ILLTYD FORMATION

Section 8

GSC loc.	Identification	Distance above base of formation (m)
90649	*Olenellus* sp.	102.5
90650	*Proliostracus amplatus* Fritz	121
90651	*Olenellus* sp. 2? Fritz, 1972	132.5
90652	*Poulsenia* sp.	143.5
90653	*Olenellus* sp. *Variopelta brevicervicata* Fritz	213.5
90654	*Salterella maccullochi* (Murchison)	219
90655	*Variopelta* sp.	230.5
90656	*Wanneria* sp.	249.5
90657	*Bonnia* sp.	267.5
90658	*Bonnia laterispina* Fritz *Wanneria logani* (Walcott)	277
90659	*Bonnia laterispina* Fritz	289.5
90660	*Bonnia quadrata* Fritz	315.5
90661	*Bonnia decora* Fritz	336
90662	*Bonnia*? sp.	387.5
90663	*Bonnia carnata* Fritz *Helcionella* sp. *Wanneria* sp.	455
90664	*Olenellus* sp.	515.5
90665	*Antagmus ducketti* Fritz *Bonnia columbensis* Resser *Paterina* sp.	562
90666	*Antagmus ducketti* Fritz *Bonnia columbensis* Resser dolichometopid trilobite *Paterina* sp. *Syspacephalus werneckensis* Fritz *Zacanthopsis expansa* Fritz	562.5
90667	*Antagmus ducketti* Fritz *Bonnia columbensis* Resser *Paterina* sp. *Zacanthopsis expansa* Fritz	571
90668	*Hyolithes* sp. *Illtydaspis quadrata* Fritz	759
90669	*Olenellus nevadensis*? (Walcott) *Olenellus parvofrontatus* Fritz *Olenellus sphaerulosus* Fritz	774–775.5
90670	*Olenellus bufrontis* Fritz *Olenellus sphaerulosus* Fritz	798.5
90671	*Bonnia* sp. *Bonnima semidiscoidea* Fritz *Illtydaspis aphylia* Fritz *Poulsenia* sp.	800.5

GSC loc.	Identification	Distance above base of formation (m)
90672	*Bonnima semidiscoidea* Fritz *Onchocephalus* sp. *Olenellus* sp. *Piaziella* sp.	821.5
90673	*Illtydaspis ornata* Fritz	851
90674	*Illtydaspis*? sp. *Olenellus romensis*? Resser	896
	SLATS CREEK FORMATION	
90675	*Amecephalus*? sp. *Fieldaspis bilobata*? Rasetti	3.5
90676	*Mexicella* sp. undetermined pychoparioid	22
90677	*Kochina*? sp. *Poliella*? sp. (cranidium only)	49
90678	*Poliella* sp.	66
90679	*Nyella* sp. *Kochina* sp.	152
90680	*Kochina*? sp. *Glossopleura* sp.	356.5
90681	*Glossopleura* sp. *Kochina* sp. *Wimanella* sp.	430.5
	TAIGA FORMATION	
90682	cf. *Polypleuraspis* sp.	134.5
	ILLTYD FORMATON **(fault slice in section)**	
90683	*Olenellus* sp. *Proliostracus contractus*? Fritz	?
	ILLTYD FORMATION **Section 9**	
89880	*Poulsenia* sp. *Proliostracus* sp.	32.5
89881	*Proliostracus* sp.	33-34.5
89882	*Bonnia columbensis* Resser	142
89883	*Bonnia columbensis* Resser	155
89884	*Bonnia* sp. *Olenellus puertoblancoensis* (Lochman)	158
89885	*Bonnia* sp. *Olenellus* sp. *Paterina* sp.	159
89886	cf. *Olenellus gilberti* Meek	182
89887	*Olenellus* sp.	442
89888	*Bonnia* sp. *Onchocephalus* sp.	462
89889	*Olenellus* sp. *Onchocephalus* sp.	818.5
89890	*Bonnia* sp. *Onchocephalus* sp.	981.5
89891	*Olenellus* sp.	1077.5

PLATES 5.1–5.4

PLATE 5.1

Figure 1. Illtyd Formation in Section 1 (view to the northeast). The basal clastic member (Units 1–4) is between points "a" and "b". The upper carbonate member (Unit 5) was measured on the slope above point "b". GSC photo 201307–S.

Figure 2. Thick bedded dolostone in the upper carbonate member of the Illtyd Formation in Section 1. The assistant, located by the arrow, is standing 94 m above the base of Unit 5. GSC photo 201307–R.

Figure 3. Illtyd Formation, unnamed breccia unit, and Vunta Formation in Section 2 (view to the northeast). The base of the section is in Vunta Creek just below the base of the photograph (Fig. 5.4). Between the base and the arrow is light to dark brownish grey weathering dolostone of the Illtyd Formation. Above the arrow is light coloured dolostone breccia of the unnamed breccia unit and Vunta Formation. GSC photo 201829–S.

Figure 4. Northwest view up Vunta Creek. Dark brownish grey Illtyd Formation is in the foreground. The base of Section 2 is at "a". Light coloured carbonates of the unnamed breccia unit and Vunta Formation crop out on the rugged slope between points "b" and "c". GSC photo 201829–W.

Figure 5. View of Section 3 looking southeast. Illtyd Formation is in the foreground. The top of Unit 2 is at "a". The contact between the carbonate buildup (Illtyd Unit 4) and laterally equivalent platy beds of Road River Formation (lower part of Unit 1) is marked by the dashed line at "b". The contact between Road River Formation and Permian strata is at "c". GSC photo 201307–T.

Figure 6. Quartet Group (HQ) and Lower Cambrian Illtyd Formation (€l) near Section 8 (view to the northwest). The dashed line marks an unconformity at the Quartet–Illtyd contact. Note the high angle dip of Quartet strata relative to the low dip of Illtyd strata. ISPG photo 1860–2 by D.K. Norris.


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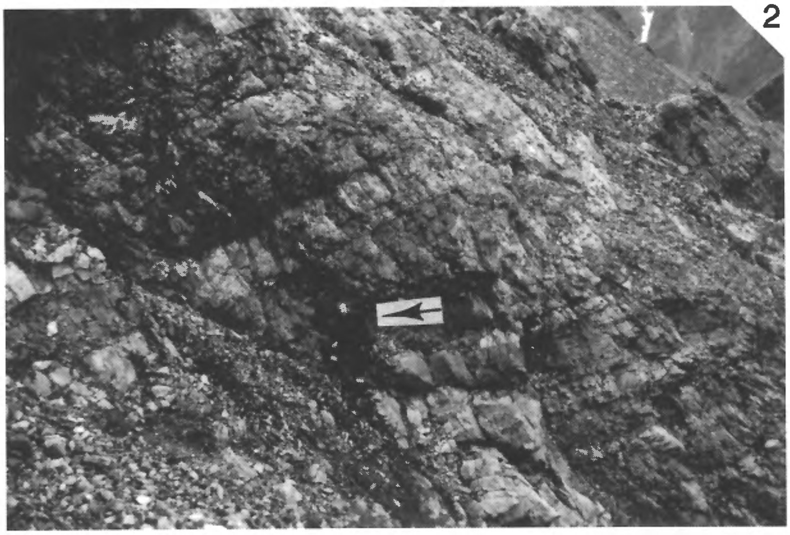
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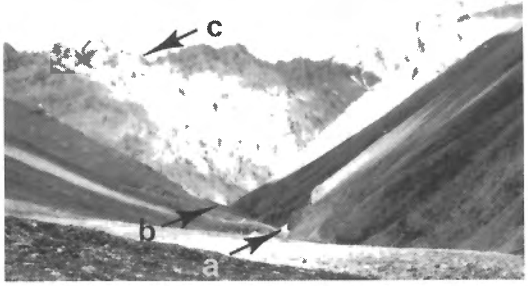
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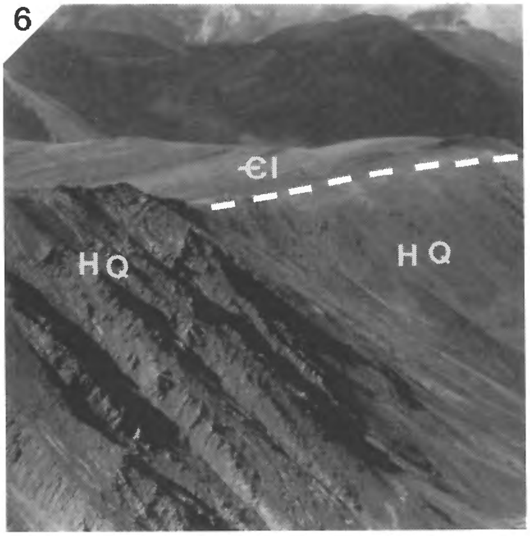
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PLATE 5.2

Figure 1. Slats Creek Formation in Section 4 (view to the northeast). Points "a", "b", and "c" are 404, 555, and 600 m above the base of the section, respectively. GSC photo 201829–T.

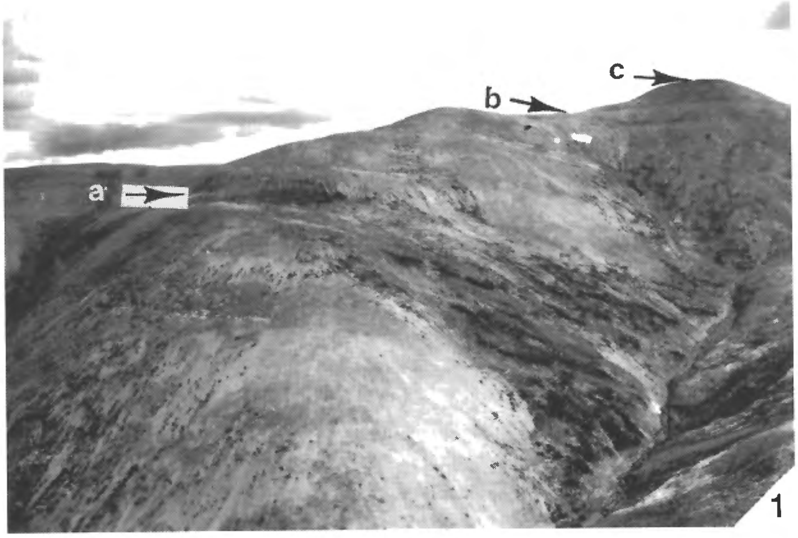
Figure 2. View of Section 5 looking northwest. Illtyd Formation was measured between points "c" and "b". The Illtyd–Slats Creek formational contact is approximately at "a". GSC photo 201307–X.

Figure 3. Illtyd Formation in Section 6 (view to the northeast). The base of the section (base of formation covered) is at "b" and the top of Unit 4 is at "a". GSC photo 201307–Q.

Figure 4. Pseudo-breccia approximately 55 m above the base of the unnamed carbonate unit in Section 6. GSC photo 201829–Z.

Figure 5. View of Section 6 looking northwest. The light coloured carbonate in the foreground belongs to Unit 5 of Illtyd Formation. Ridge "b" is underlain by Slats Creek Formation. Arrow "a" marks the contact between Slats Creek and the overlying unnamed carbonate formation. GSC photo 201829.

Figure 6. Conglomerate in Slats Creek Formation 48 m below Slats Creek–unnamed carbonate formational contact in Section 6. GSC photo 201829–U.



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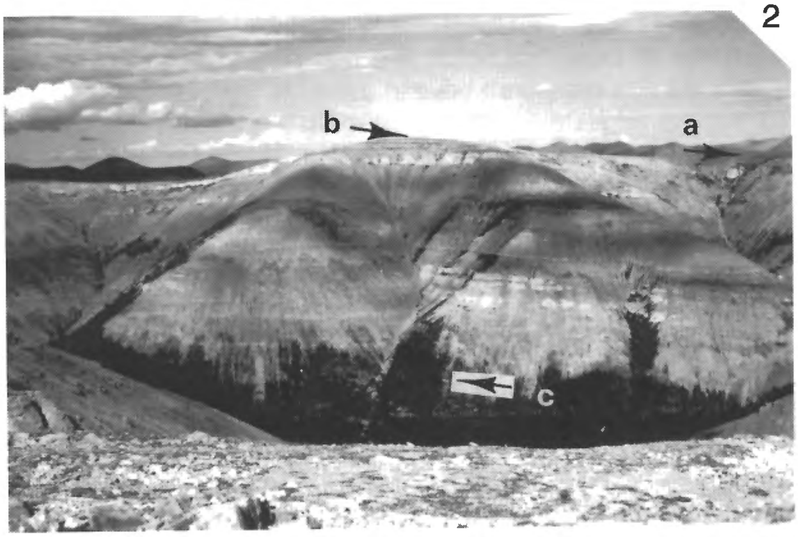

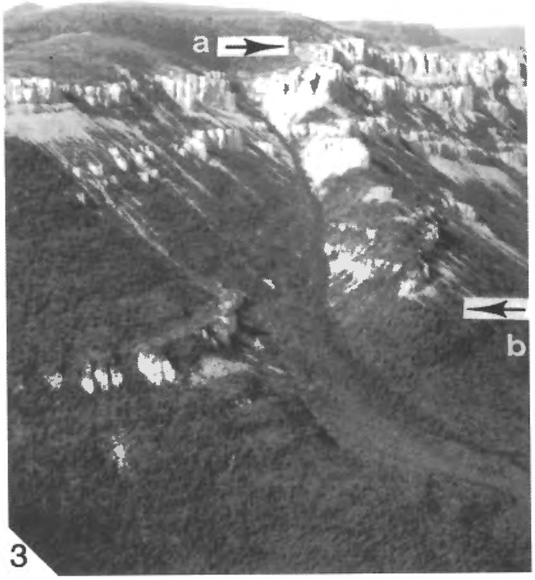

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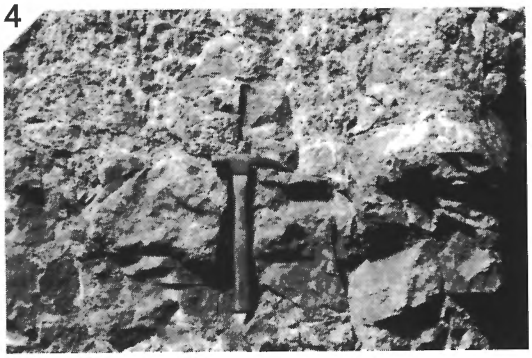

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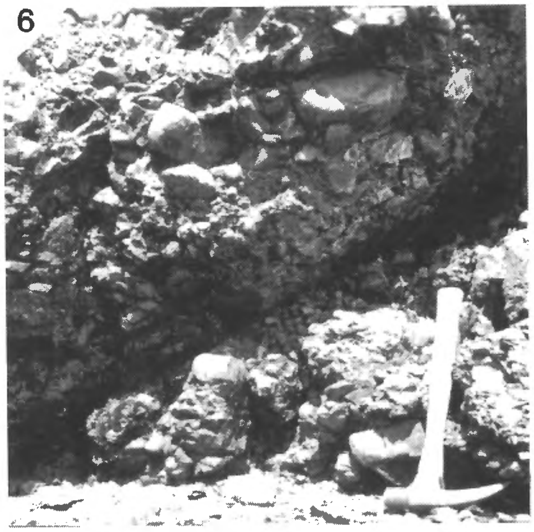

PLATE 5.3

Figure 1. View of Section 8 looking south. The section starts in gully "f" below the base of the photograph at the Illtyd–Quartet Group contact. The lower siltstone member of Illtyd Formation is between the contact and point "e". The upper carbonate member is between points "e" and "d". Slats Creek Formation was measured along the ridge between "d" and "c". Taiga Formation was measured from "c" over the small ridge and into the saddle between points "c" and "b". The remainder of Taiga Formation and part of the unnamed carbonate formation (segment 8c in Fig. 5.4b) was measured beyond the ridge behind point "a". In the background, light coloured, rugged ridges (i.e., ridge at point "b") are underlain by an unnamed carbonate formation. Wind River is in the centre background. This figure is a modification of Fritz's (1991), Plate 1, figure 1, and is a composite of GSC photos. 200875–Q, 200875–R, 201307–P.

Figure 2. The lower siltstone member of the Illtyd Formation (view to the west) exposed between points "a" and "b". The gully in the centre of the photograph is located at "f" in Figure 1. GSC photo 201307–W.

Figure 3. View of Section 8 looking south. The Illtyd–Slats Creek formational contact is at "b", and Unit 2 in Slats Creek Formation is at "a". GSC photo 201829–V.

Figure 4. Illtyd Formation near Section 9 (view to south). Contact between Illtyd (left) and Precambrian strata (right) is approximately at "b". Peak "a" behind the ridge in the foreground is on the line with Section 9. GSC photo 201307–U.


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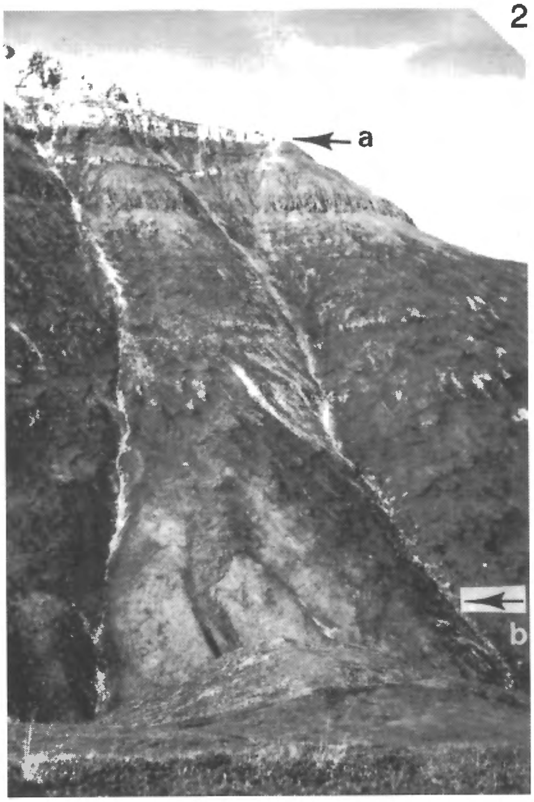
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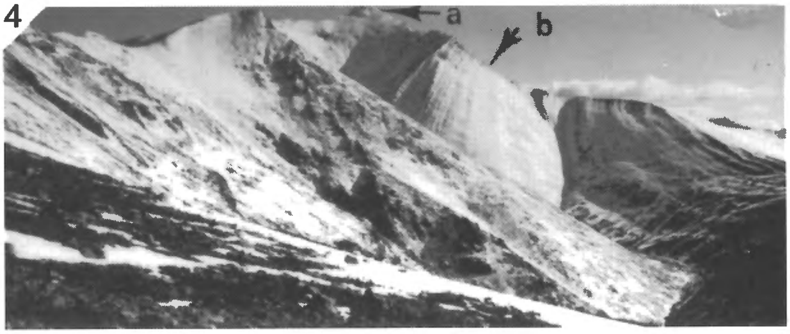
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PLATE 5.4

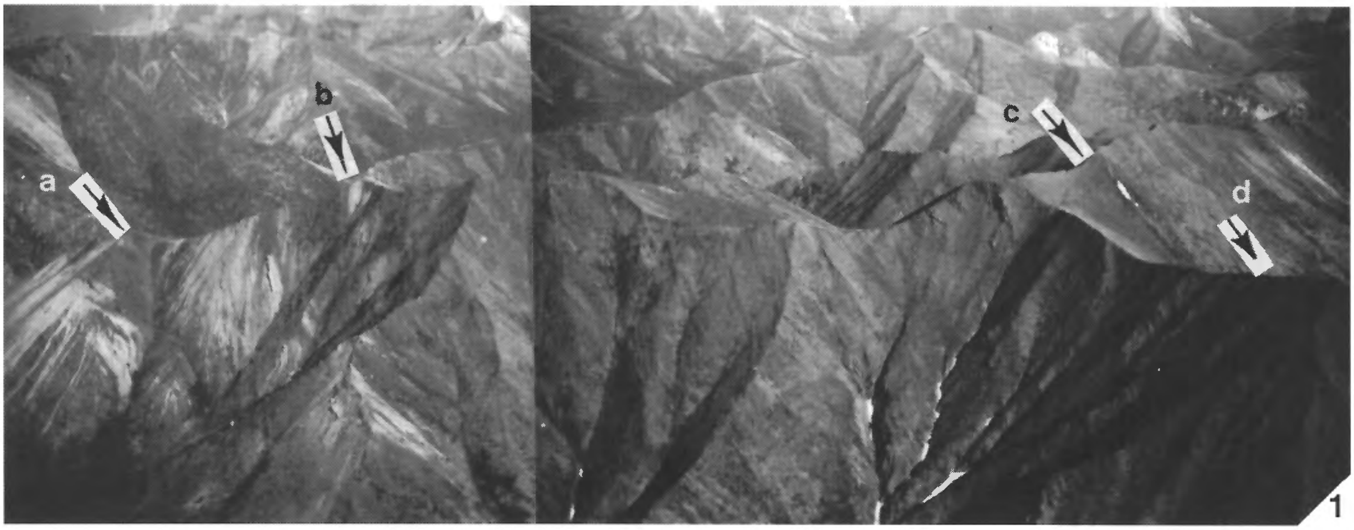
Figure I. Slats Creek Formation in Section 7 (view to the east). Contact between Precambrian strata and the Slats Creek is at "a", Unit 3 is at "b", top of segment 7a (top of Unit 4) is at "c". Ridge "d" is underlain by Slats Creek conglomerate. Segment 7b starts on the north slope of the ridge (Unit 5), extends southward over the ridge crest (Unit 6), and down the south slope (Unit 7). This figure is a composite of GSC photos. 201307–Y, 201829–X.

Figure 2. Lower part (Units 1, 2) of Taiga Formation in Section 7 (view to the southwest). The striped appearance is due to contrast in both colour and resistance of successive beds. Contact between Unit 2 and Unit 3 is approximately at "a". GSC photo 201307–Z.

Figure 3. Upper part (Units 3, 4) of Taiga Formation (view to the southeast). The base of Unit 3 is at "a" and the top of Unit 4 is at "b". GSC photo 200875–T.

Figure 4. Cambrian outcrops along Tatonduk River, Alaska (view to the northwest). Lower Cambrian Funnel Creek and Adams Argillite formations are at "a" and "b", respectively. Lower to Upper Cambrian Hillard Formation is at "c". GSC photo 200875–S.

Figure 5. Jones Ridge Limestone near the Yukon/Alaska border. The large, irregular limestone mounds contain archaeocyathids. GSC photo 201307–V.



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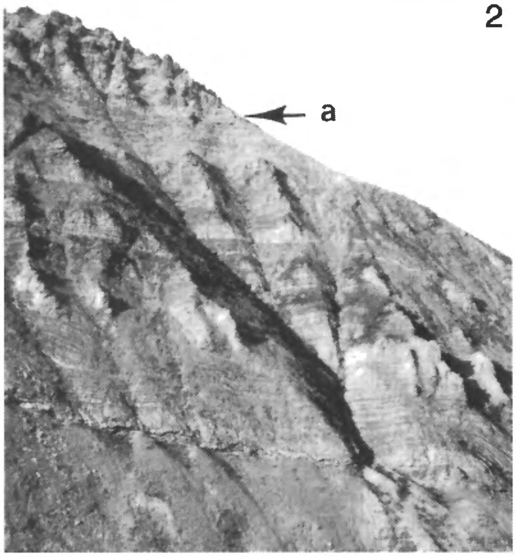

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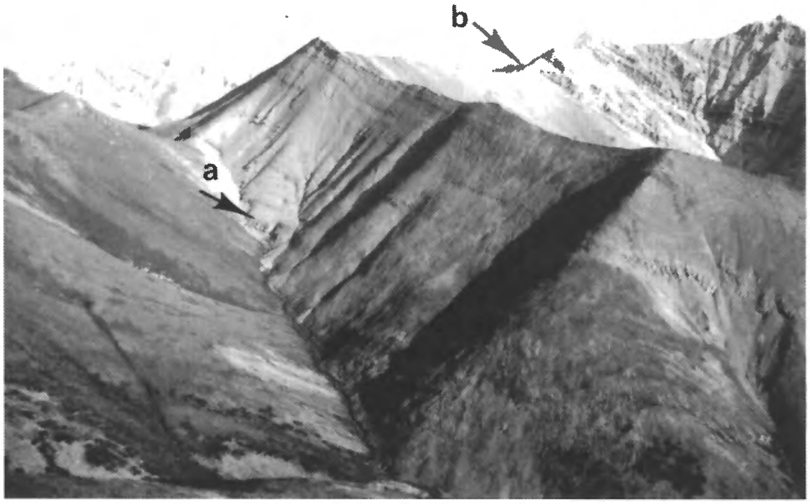

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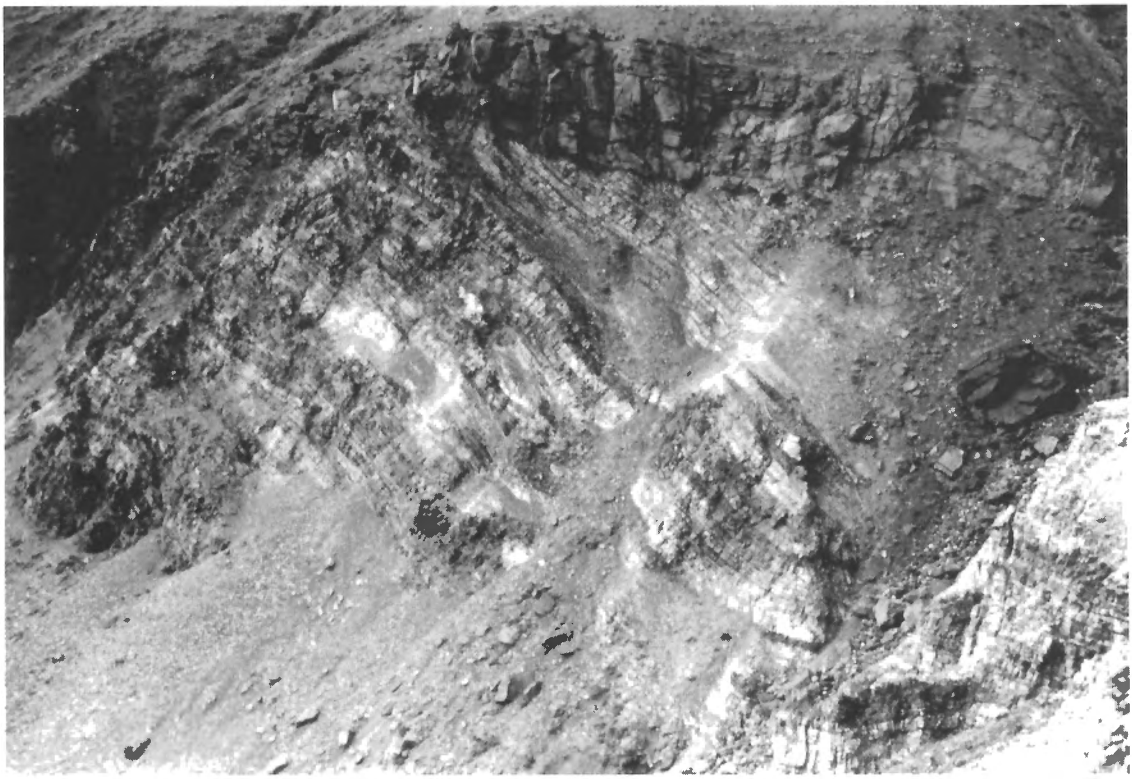


Angular unconformity between unnamed Permian clastics and lower Paleozoic Road River Formation along the east face of the Aklavik Range, N.W.T. GSC photo 3650-2.

CHAPTER 6

ORDOVICIAN AND SILURIAN

B.S. Norford

Norford, B.S., 1996. Ordovician and Silurian. In The Geology, Mineral and Hydrocarbon Potential of Northern Yukon Territory and Northwestern District of Mackenzie. Geological Survey of Canada, Bulletin 422, p. 119–162.

Abstract

During the early Paleozoic, the paleogeography of northern Yukon and adjacent District of Mackenzie was characterized by an intricate and changing pattern of platforms and adjacent troughs. Relatively deep water persisted in the Richardson and Blackstone troughs throughout most of the Late Cambrian to Early Devonian. Carbonate rocks accumulated on shallow shelves and banks that bordered the two troughs, and carbonate sediments were shed into the basinal depositional environments of the troughs.

Unconformities are widespread within the carbonate successions of the Mackenzie Arch and the Porcupine Platform and can be detected locally on the Ogilvie Arch. In contrast, there is little evidence of breaks in the carbonate banks of the White Uplift and the Illtyd Range, located at the north and south ends of the Richardson Trough respectively. The Richardson Trough subsided throughout the interval and the resulting Road River strata have a virtually complete biostratigraphic record spanning some 120 million years.

Thermal maturation studies indicate that most of the Ordovician and Silurian rocks have been heated too severely for the retention of oil and gas generated within the sediments. Little is known of the potential for base metal deposits, but the setting is analogous to those of the Selwyn Basin and the Kechika Trough, where significant discoveries have been made of strata-bound deposits in basinal facies. Volcanics are prominent in the Road River Group in those areas, but some possible ash components of micrites are the only records of volcanic activity in the Road River Group in the Richardson and Blackstone troughs.

Résumé

Durant le Paléozoïque précoce, la géographie du nord du Yukon et du district du Mackenzie adjacent était caractérisée par un réseau compliqué et changeant de plates-formes et de cuvettes contiguës. Des nappes d'eau relativement profondes ont persisté dans les cuvettes de Richardson et de Blackstone pendant presque toute la période allant du Cambrien tardif au Dévonien précoce. Les roches carbonatées se sont accumulées sur des plates-formes peu profondes et des bancs bordant les deux cuvettes; les sédiments carbonatés ont été évacués vers les cuvettes, milieux de sédimentation de type bassin.

Les discordances sont nombreuses dans les successions carbonatées de l'arche de Mackenzie et de la plate-forme de Porcupine et l'on peut en détecter localement sur l'arche d'Ogilvie. Par contre, on a retracé peu d'indices de ruptures dans les bancs carbonatés du soulèvement de White et du chaînon d'Illtyd, situés respectivement dans les extrémités nord et sud de la cuvette de Richardson. Celle-ci s'est affaissée durant tout l'intervalle et les couches résultantes de Road River présentent un profil biostratigraphique pratiquement complet s'échelonnant sur quelque 120 millions d'années.

Les études portant sur la maturation thermique indiquent que la plupart des roches ordoviciennes et siluriennes ont été trop chauffées pour permettre la rétention de pétrole et de gaz formés dans les sédiments. On connaît peu de choses sur le potentiel en gisements de métaux communs, mais le milieu est analogue à ceux du bassin de Selwyn et de la cuvette de Kechika, où l'on a fait d'importantes découvertes de gisements stratiformes dans des faciès de bassin. Les volcanites sont répandues dans le Groupe de Road River de ces régions, mais la présence possible de cendres dans les micrites serait le seul indice d'activité volcanique dans le Groupe de Road River dans les cuvettes de Richardson et de Blackstone.

INTRODUCTION

Early geological investigations in widely separated areas of northern Yukon and adjacent District of Mackenzie reported the presence of Ordovician and Silurian limestones, dolomites and graptolitic facies (Cairnes, 1914; Kindle, 1914; Stelck, 1944; Hume and Link, 1945; Decker et al., 1947; Gabrielse, 1957). Extensive surface exploration in the late Fifties by a number of oil companies provided a great deal of data that remains unpublished. Later work outlined the distribution of the Ordovician and Silurian rocks, gave some local details of transitions between the carbonate facies and the basinal (graptolitic) facies and presented regional paleogeographic interpretations for various specific intervals of early Paleozoic time (Martin, 1959; Jackson and Lenz, 1962; Norris et al., 1963; Norford, 1964; Churkin and Brabb, 1965, 1968; Lenz, 1972; Macqueen, 1974, 1975). Pugh (1983) studied the subsurface geology of the region and updated Tassonyi's (1970) study of the Mackenzie Valley and the Anderson Plain. This chapter is a synthesis of all data available at mid 1989 with emphasis on the author's 1962 field studies (Norford, 1964, contains detailed stratigraphic sections), a restudy of selected material collected during that summer's reconnaissance, and biostratigraphic studies of detailed stratigraphic sections studied by M.P. Cecile in 1982 and of relevant core material from exploratory wells (Norford, 1972, 1973a).

FACIES RELATIONSHIPS

Except for a few very localized features, the whole region was marine throughout Ordovician and Silurian time and lay at the edge of, and beyond, the shallow carbonate shelf that bordered the exposed North American craton (Fig. 6.1). The overall concept is that of positive areas in a region of progressively deepening water, with carbonate banks maintaining themselves throughout the Ordovician and Silurian in some areas but being transgressed by basinal rocks in others (Figs. 6.2–6.9). Platform margin and slope deposits are preserved near the fronts of some of the banks and indicate considerable subsea relief. Unconformities conceal knowledge of parts of the histories of some areas: rocks may have been deposited during parts of the stratigraphic gaps and removed by later erosion; or the areas may have been so positive as to be above sea level and lacking sediments throughout the hiatuses represented by the unconformities.

Only very fine sediment reached the region from the land areas of the North American craton. Parts of the shelf were exposed from time to time during regressions, some of which are documented by unconformities that extend westward into parts of the basinal environments. There has been some speculation that extreme northern Yukon (Fig. 6.1, locs. 24, 41, 90, 94) includes terrain exotic to the North American continent. However, the basinal rocks of the Barn Mountains (Fig. 6.1, loc. 41) show lithological similarities to coeval rocks in the western part of the Selwyn Basin of central Yukon (Cecile, 1988) and this northern area can be considered to be depositionally contiguous with the rest of the region.

The dominant paleogeographic feature in Ordovician and Silurian time was the Richardson Trough. In the Early Ordovician (Figs. 6.2, 6.3), the trough was a narrow depression of basinal sedimentation, bordered to the east and west by carbonate banks, but with an incipient southwestern extension, the Blackstone Trough. By the Middle Ordovician (Fig. 6.4), the Blackstone Trough was well established and presumably continuous with the Tatonduk River region near the Yukon/Alaska border where high Lower Ordovician and younger basinal facies rest directly on Upper Cambrian carbonates (Churkin and Brabb, 1965, p. 177). In addition, there was a connection with the deep-water facies of the Selwyn Basin around the western and southern margins of the carbonate bank at the Ogilvie and Wernecke mountains. By Late Ordovician time (Fig. 6.5), the basinal facies (Road River Group) of the Blackstone and Richardson troughs had encroached onto parts of the Porcupine Platform and the Ogilvie Arch.

Expansion of the area of basinal sedimentation continued throughout the Silurian (Figs. 6.6–6.9). During the mid-Early Silurian (*Monograptus turriculatus* Zone, Fig. 6.7), an intermittent connection may have existed from the Richardson Trough directly southward through the Royal Creek headwaters area (Fig. 6.1, loc. 82; Green, 1972, p. 33), to the Misty Creek Embayment (Cecile, 1982) of the Selwyn Basin. The encroachment of the basinal facies was probably at its maximum in the Late Silurian and Early Devonian (Figs. 6.8, 6.9), but carbonate banks persisted on the Ogilvie Arch, in the White Uplift, on the Mackenzie Arch and on the Porcupine Platform where Moorehouse (1966) has suggested eastward withdrawal of the basinal facies in Late Silurian time.

STRATIGRAPHY - CARBONATE FACIES

Present knowledge of the detailed stratigraphies of the carbonate banks is inadequate for formal nomenclature except in the Mackenzie Arch and in the isolated sequence of the White Uplift (Figs. 6.10–6.13). For convenience, the rocks of the carbonate facies can be discussed in terms of five regions (Fig. 6.1): Mackenzie Arch, Ogilvie Arch, Porcupine Platform, White Uplift and Campbell Uplift. Each is discussed as an outcrop area but most of the banks extend into the subsurface. Carbonate rocks have been reported from a number of exploratory wells; many of these rocks represent carbonate banks but some may be debris flows within basinal facies.

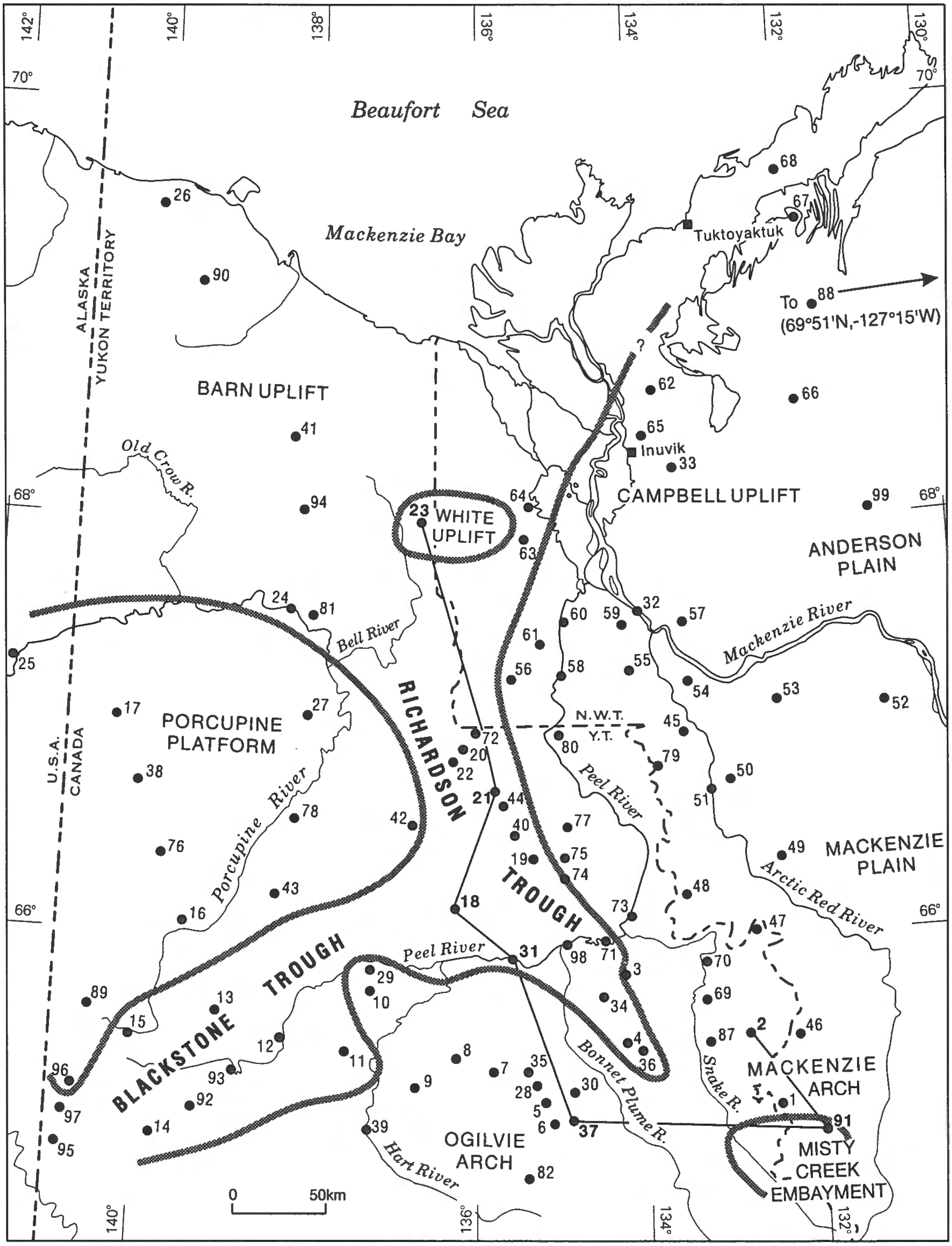
Mackenzie Arch

The Mackenzie Mountains extend westward just into northern Yukon. Their Upper Cambrian to Lower Devonian stratigraphic package is distinct and widely distributed, not only in the Mackenzie Mountains but also throughout the Mackenzie Valley, Great Slave Plains, Great Bear Plains and Anderson Plains. The carbonate units (Fig. 6.10: Franklin Mountain, Mount Kindle, Delorme equivalent, Peel and Gossage) document only parts of the time interval (Norford and Macqueen, 1975); hiatuses between and within the formations represent regressions when shorelines were farther to the west.

Within the Franklin Mountain Formation, four widely distributed units and a local basal unit can be recognized shoreward from the front of the carbonate platform. These units are developed most clearly in the Mackenzie Valley and in Anderson Plain but lose definition westward toward the change of facies into the coeval Road River Group. Only the upper two units (cherty unit, porous dolomite unit) are known to be Ordovician and their distribution and thickness are erratic because of erosion prior to the sub-Mount Kindle (late Caradoc) and later unconformities.

At the Canyon Ranges Section (Fig. 6.1, loc. 2) near the western front of the carbonate platform, the Franklin Mountain Formation is 485 m thick but its subdivisions are indistinct. Upper Cambrian fossils are present about 120 m above the base (Norford and Macqueen, 1975, p. 36). The Ordovician part of the Franklin Mountain Formation consists of about 300 m of platy limestones and evenly bedded dolomites. Resistant dolomites of the Mount Kindle Formation (about 235 m thick) overlie an erosion surface and are similar to the rocks in the type area (op. cit.). The basal member is not developed, the middle member is about 72 m thick, the less resistant upper member (about 163 m thick) weathers yellowish grey and light grey but includes a number of darker grey weathering beds, some of which are biostromal.

In the Mackenzie Mountains, an Upper Silurian to Devonian succession follows the Mount Kindle Formation, probably disconformably (Norris, 1968, p. 20). Norris originally assigned these rocks to the Gossage Formation; since then most of the lower part has been considered to be a basal part of the Delorme Formation(?) (Macqueen, 1974), the SD Unit (Aitken et al., 1982), or more recently the Peel Formation (Pugh, 1983) and an unnamed carbonate unit (Norris, 1985, p. 10). The rocks are dolomites (about 60 m thick) that weather distinctively in yellowish grey and yellowish orange. At three localities west of the Canyon Ranges Section, platy limestones are present between the Peel and Mount Kindle formations. At its westernmost point (MQ-10, Macqueen, 1974, p. 325; Fig. 6.1, loc. 36, 33 km from the Canyon Ranges Section), this limestone unit is about 90 m thick and contains Upper Silurian (Ludlow) brachiopods in talus 25 m above its base (GSC loc. C-26676, including *Atrypoidea* and *Conchidium* sensu stricto). About 16 km east and 19 km southeast of MQ-10, the unit is about 15 m thick at two localities studied by Lenz (Broad and Lenz, 1972; Dineley, 1965). Two kilometres north of the locality of Broad and Lenz, the unit may be present in the basal part of a stratigraphic section west of Snake River (Norris, 1968, p. 134, units 5 to 9, 8 m thick) where the beds above the Mount Kindle Formation are poorly exposed. The unit was not seen at the Canyon Ranges Section (about 29 km farther east) where the base of the Peel Formation is largely covered by talus. The unit may be present but not exposed at this location; alternatively it may be



Line of section, Fig. 6.12 .... 23●——●2

Figure 6.1. Locality map.

Legend

1. Cranswick River Headwaters Section (106F5)*
2. Canyon Ranges Section (106F13)
3. Trevor Range Section (106E8)
4. Knorr Range Section (106E14)
5. South Illtyd Range Section (106E5)
6. Royal Creek Section (106E15)
7. Prongs Creek Section (106E21)
8. Clear Creek Section (116H5)
9. Pat Lake North Section (116H10)
10. Blackstone River North Section (116H8)
11. Blackstone River Section (116H15)
12. Ogilvie River Section (116G8)
13. Nahoni Range Section (116G4)
14. Monster River Headwaters Section (116C1)
15. Tatonduk River Headwaters Section (116F4)
16. Mount Burgess Section (116J5)
17. Keele Range Section (116K4)
18. Canyon Creek Section (116I1)
19. Trail River Section (106L4)
20. James River Section (M.P. Cecile, pers. comm., 1983)
21. Tetlit Creek Section (106L2)
22. Rock River Section (116I2)
23. Fish Creek Section (116P7)
24. Lower Porcupine River Section (116O7)
25. Old Ramparts, Porcupine River
26. GSC locality C-41895, Komakuk Beach
27. Peel Plateau Eagle Plains No. 1 well
28. Wind River West Section (MQ14-75) (106E19b)
29. S.O.B.C. Blackstone D-77 well
30. Wernecke Mountains Section (MQ13-75) (106E20)
31. Peel River Upper Canyon Section
32. Point Richfield et al. Separation No. 1 well
33. Campbell Lake Section (A.W. Norris) (107B2)
34. Noisy Creek Locality
35. North Illtyd Range Section (MQ11-74) (106E6b)
36. Knorr Range Section (MQ10-74) (106F14)
37. Royal Mountain Locality (MQ16-74/75) (106E12)
38. Keele Range Locality (Dean, 1973) (116K2)
39. GSC loc. 47050 (Green, 1972)
40. Road River
41. Barn Mountains Locality N74 (Lenz and Perry, 1972)
42. Socony-Mobil-W. Min. South Tuttle N-05 well
43. Socony-Mobil-W. Min. North Cath. B-62 well
44. GSC loc. C-104242 (M.P. Cecile, pers. comm., 1983)
45. I.O.E. Martin House L-50 well

*Sections described during Operation Porcupine are designated by the National Topographic System map area on which they appear, followed by a section number (e.g., 106F5). They are identified in the same manner throughout this volume and correspond to sections designated on the 1:250 000 scale geological maps of the project area.

46. Amoco PCP-A1 Cranswick A-22 well
47. Inexco et al. Weldon Creek O-65 well
48. Arco-Shell Sainville River D-08 well
49. Atlantic et al. Ontaratue H-34 well
50. Shell Arctic Red River O-27 well
51. Shell Arctic Red River G-55 well
52. Richfield et al. Grandview Hills No. 1 well
53. Shell Tree River F-37 well and H-57 well
54. I.O.E. Clare F-79 well
55. I.O.E. Nevejo M-05 well
56. Union-Amoco McPherson B-25 well
57. Inc.-NCo-Mobil Attoe Lake I-06 well
58. I.O.E. Stony I-50 well
59. Shell-Getty-Amoco Ft. McPherson C-78 well
60. Bluemount et al. Gulf S. Delta J-80 well
61. Dome-Union-I.O.E. Stony G-06 well
62. Gulf East Reindeer C-38 well
63. Banff-Aquitaine-Arco Rat Pass K-35 well
64. Union Aklavik F-38 well and A-37 well
65. Amoco-Ulster-Scurry Inuvik D-54 well
66. C.P.O.G. Kugaluk N-02 well
67. Elf et al. Kiligvak I-29 well
68. I.O.E. Natagnak K-23 well
69. Amoco-P.C.B. B-1 Cranswick A-42 well
70. McD.-G.C.O.-Northrup Taylor Lake K-15 well
71. Toltec Peel River N-77 well
72. Vittrekwa River
73. Shell Peel River M-69 well
74. Gulf-Mobil Caribou N-25 well
75. Mobil-Gulf Peel River H-71 well
76. Inexco Husky et al. Porcupine G-31 well
77. Shell Trail River H-37 well
78. Western Minerals North Hope N-53 well
79. Skelly-Getty-Mobil Arctic Red C-60 well
80. Pacific et al. Peel F-37 well
81. Westcoast et al. Porcupine F-72 well
82. Royal Creek Headwaters Section (Lenz, 1967)
88. Elf Horton River G-02 well (69°51'N, 127°15'W, Yorath et al., 1975)
89. Tindir Creek headwaters
90. Firth River (Lane and Cecile, 1989)
91. SW Upper Ramparts River Section (Cecile, 1982, Section 1)
92. Mt. Skookum Jim
93. Mt. Bouvette
94. Johnson Creek Headwaters
95. Hillard Peak
96. Jones Ridge South (Churkin and Brabb, 1968)
97. Hard Luck Creek, Tatonduk River Locality (Brabb, 1967)
98. Peel River Lower Canyon Section
99. C.D.R. Tenlen A-73 well (Mackenzie, 1974)

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missing beneath the sub-Peel unconformity. The stratigraphic attenuation eastward supports the latter interpretation. Fish from the Peel Formation have been dated as Early Devonian or latest Silurian (Dineley, 1965; Broad and Lenz, 1972) and high Ludlow conodonts (*siluricus* Zone to *latialata* Zone) are present near the base of the unit in the Canyon Ranges Section (Appendix, GSC loc. 53153).

Northwest of the Mackenzie Mountains, the Mount Kindle and Franklin Mountain formations are much thicker just west of the Trevor Range (Fig. 6.1, loc. 3); have lost many of their characteristic features; and, in part, have changed facies into the Road River Group (B.P. Plauchut, pers. comm., 1967).

Ogilvie Arch

In the Wernecke and Ogilvie mountains, and in the subsurface of the adjacent Eagle Plain to the north, upper Upper Cambrian, Ordovician, Silurian and Lower Devonian carbonates form a very thick resistant unnamed unit (map unit ꞒD; Fig. 6.14) that locally approaches 1800 m thick (Green, 1972, p. 34; Martin,

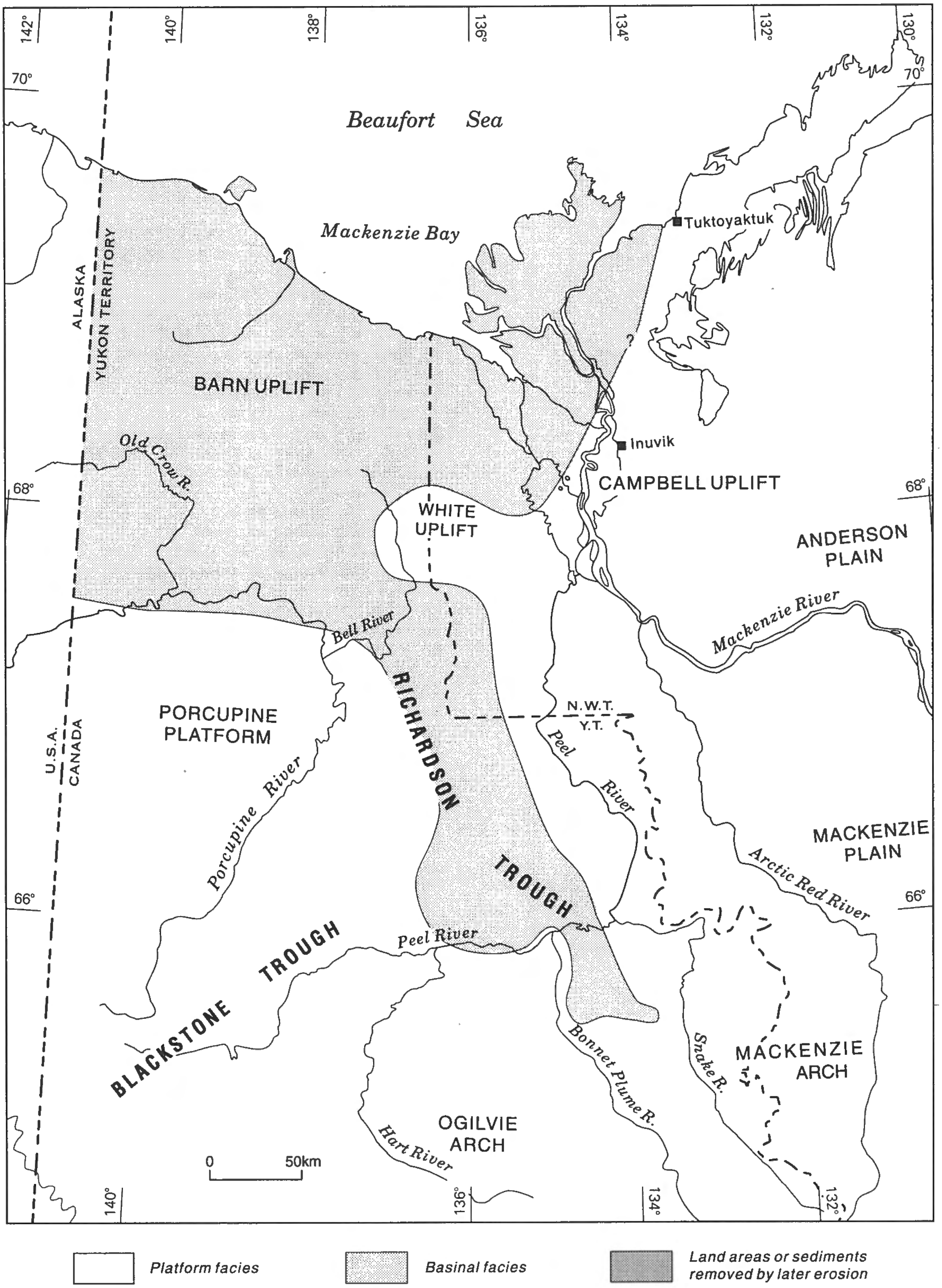

Figure 6.2. *Paleogeographic map, early Early Ordovician time (early Tremadoc).*

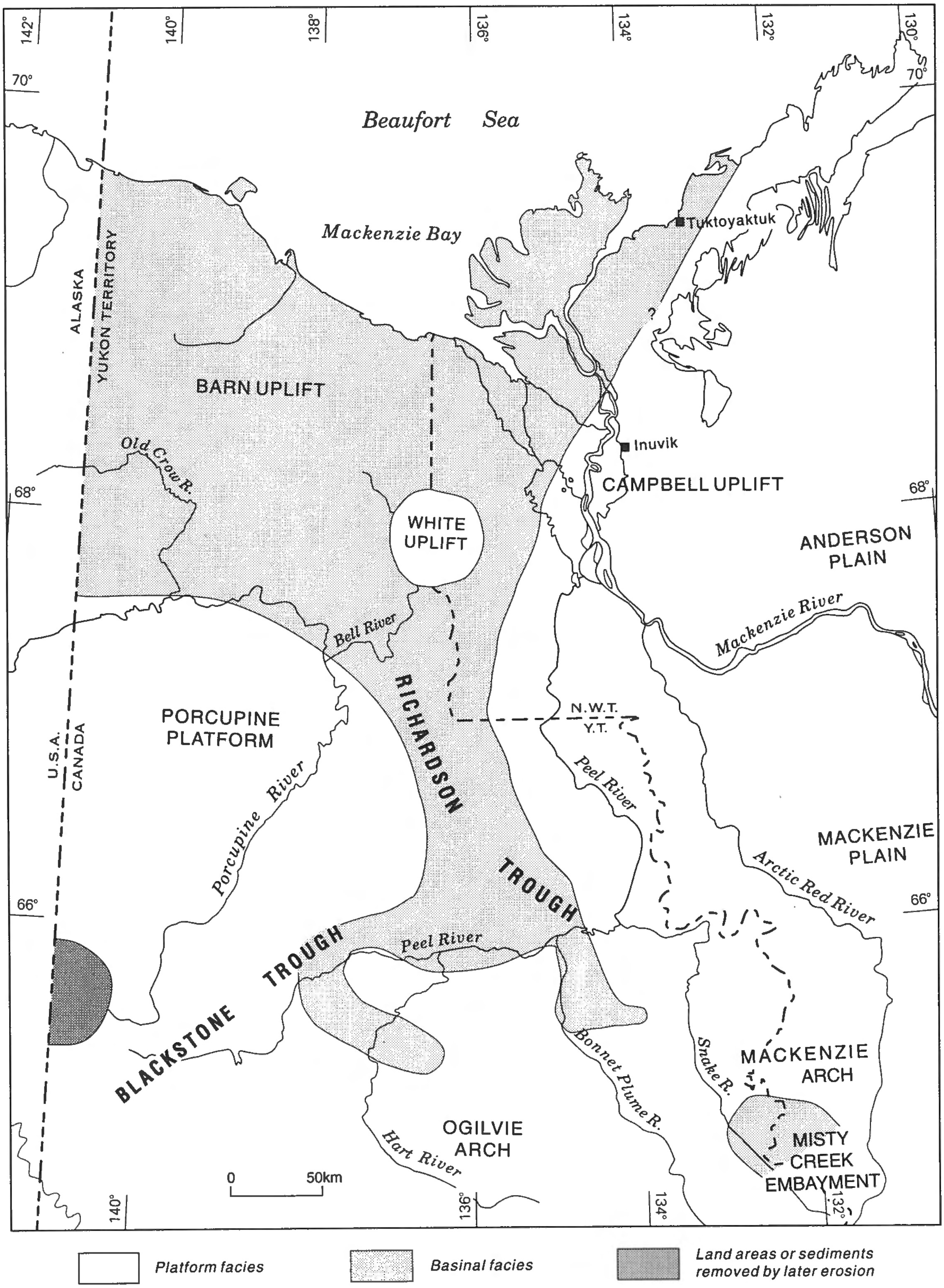

Figure 6.3. Paleogeographic map, late Early Ordovician time (early Arenig).

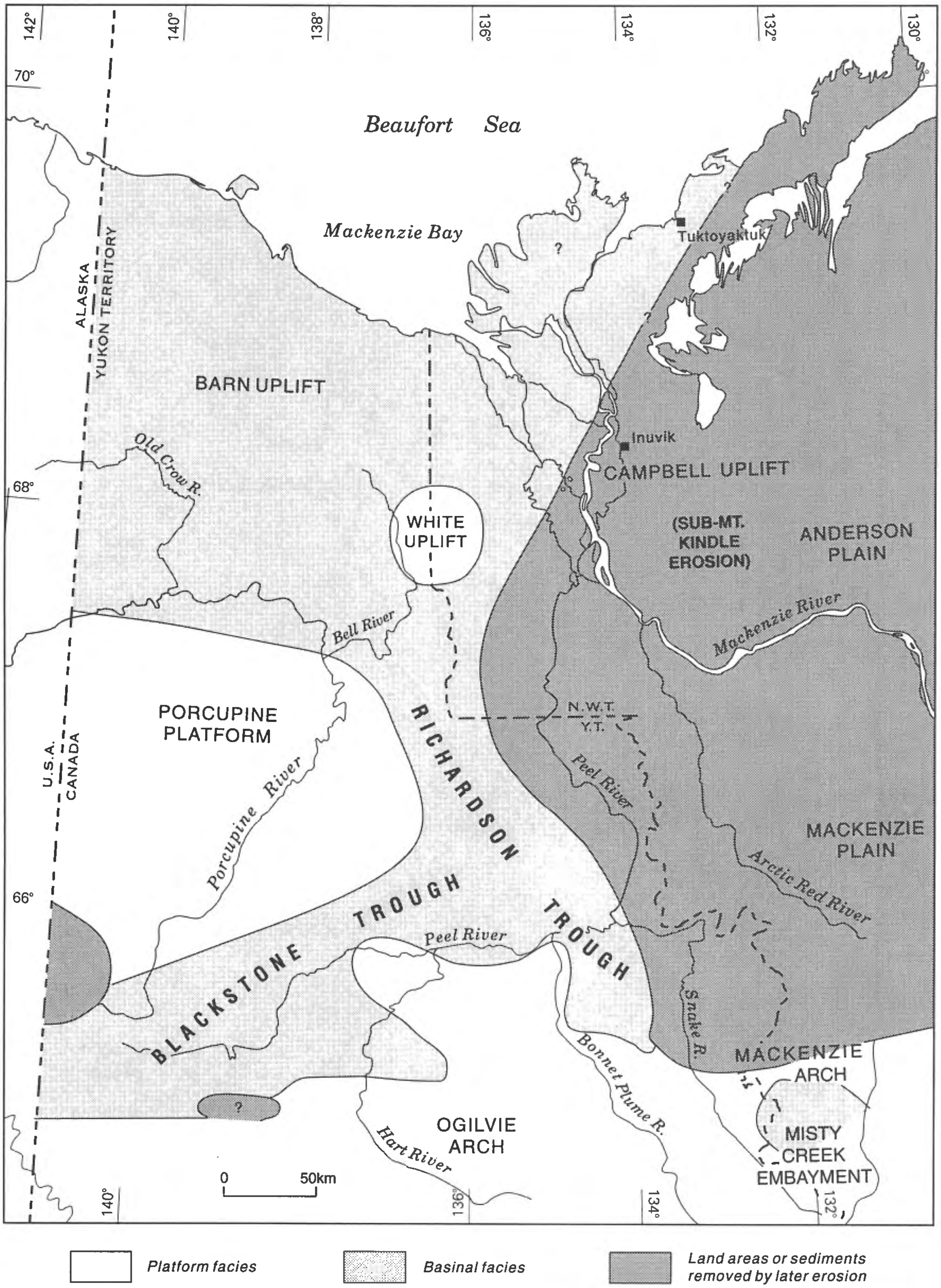

Figure 6.4. *Paleogeographic map, early Middle Ordovician time (Llandeilo).*

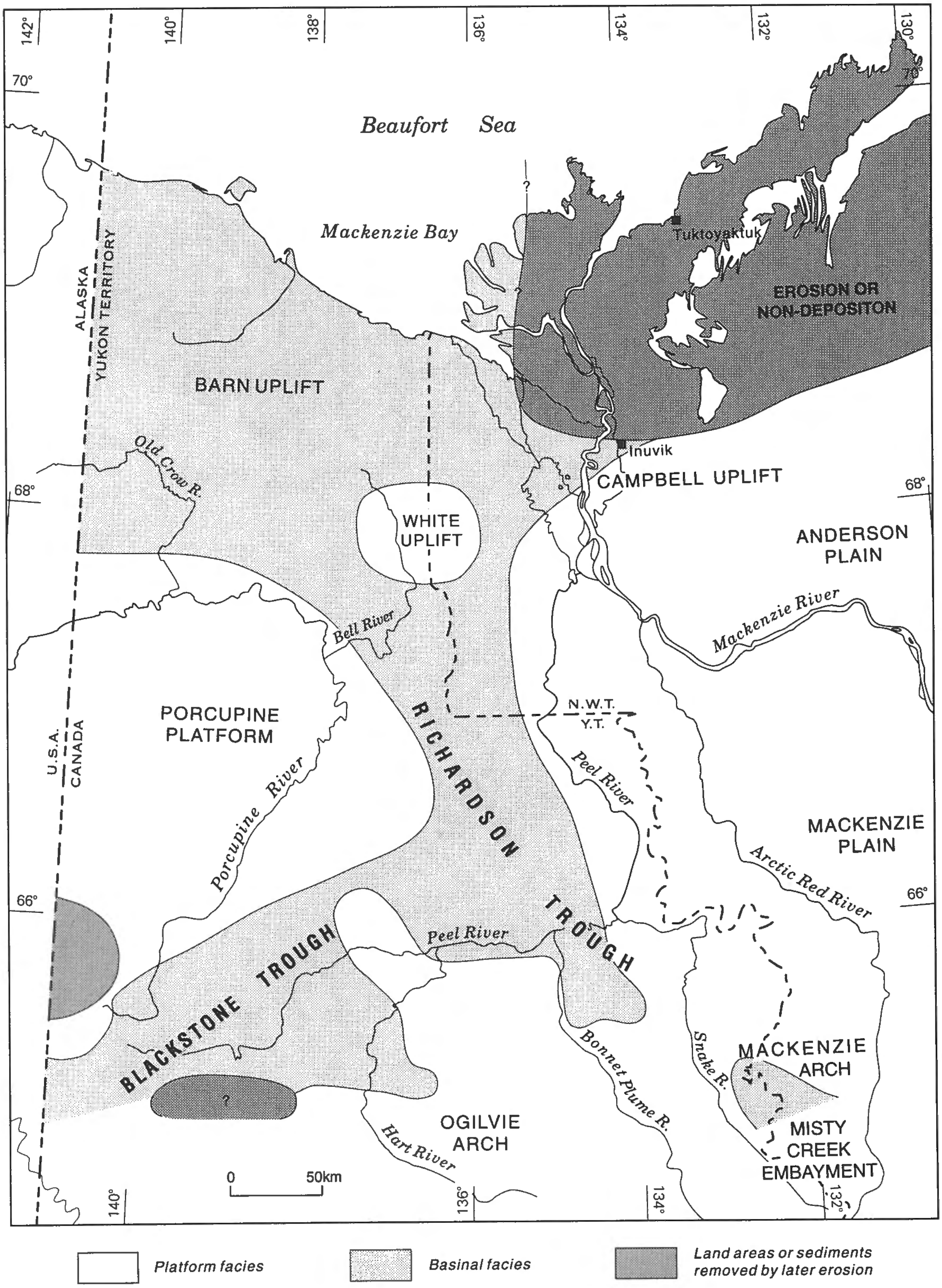

Figure 6.5. *Paleogeographic map, Late Ordovician time (late Caradoc).*

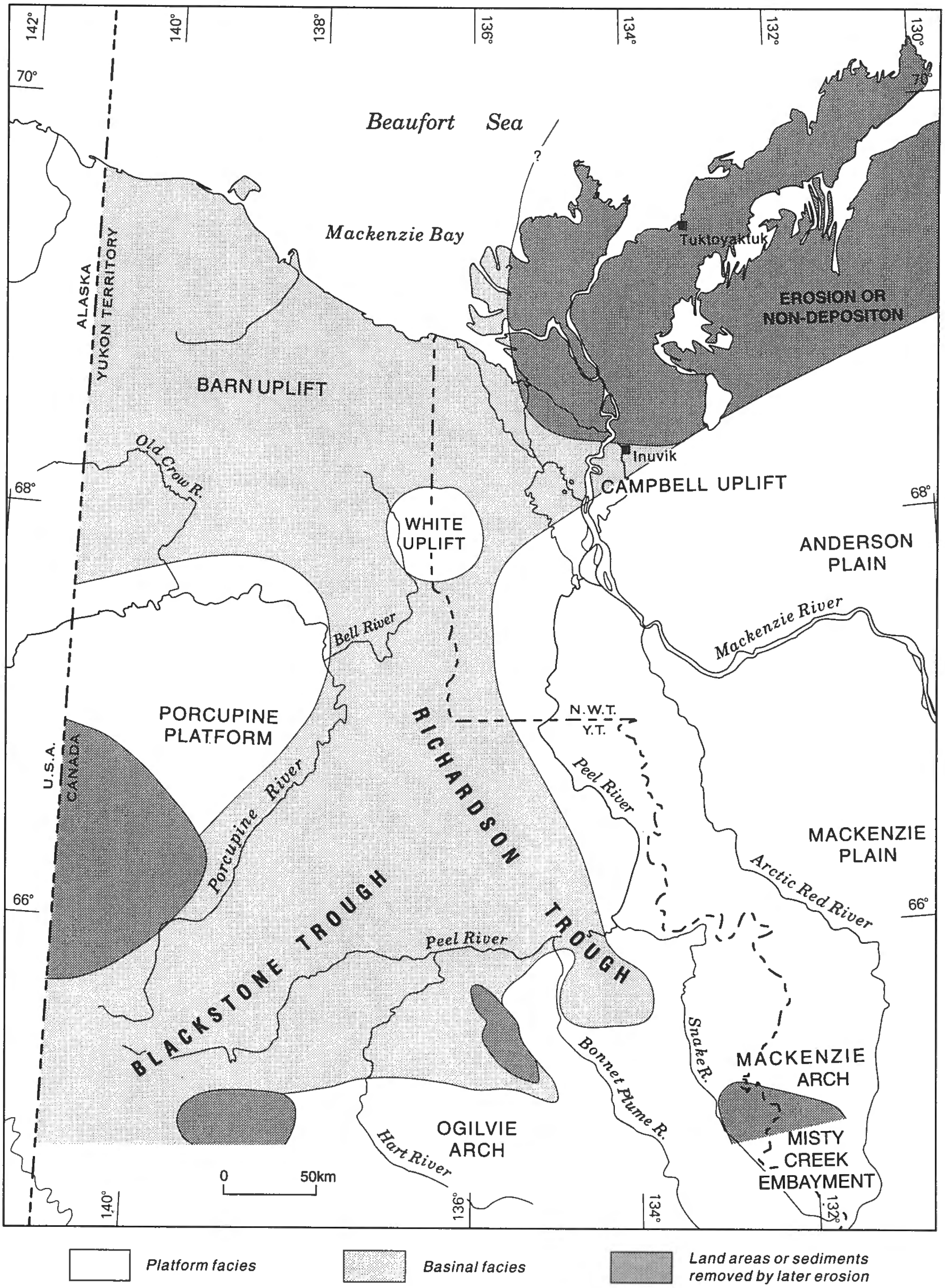

Figure 6.6. Paleogeographic map, early Early Silurian time (Middle Llandovery).

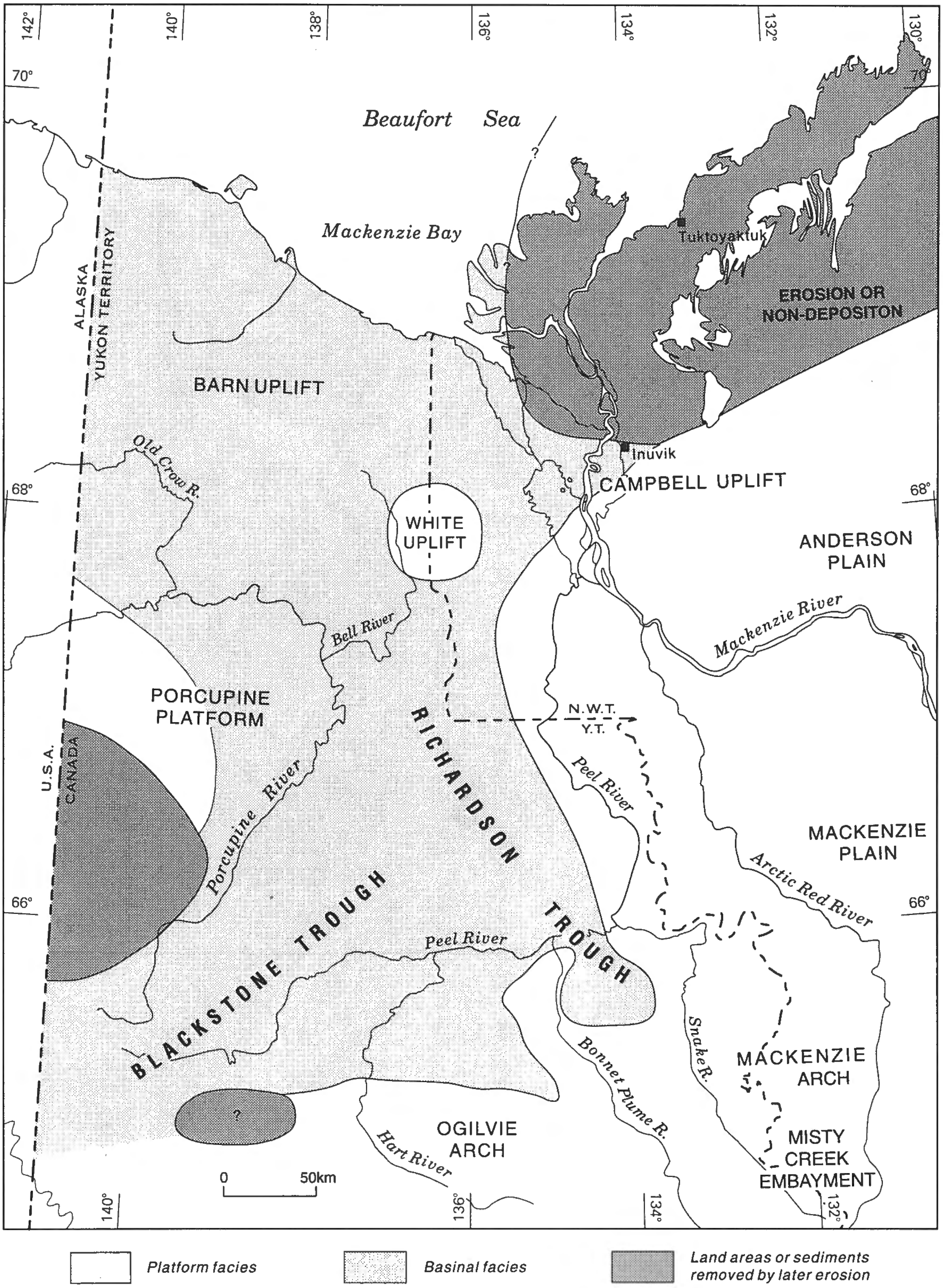

Figure 6.7. *Paleogeographic map, mid Early Silurian time (Late Llandovery).*

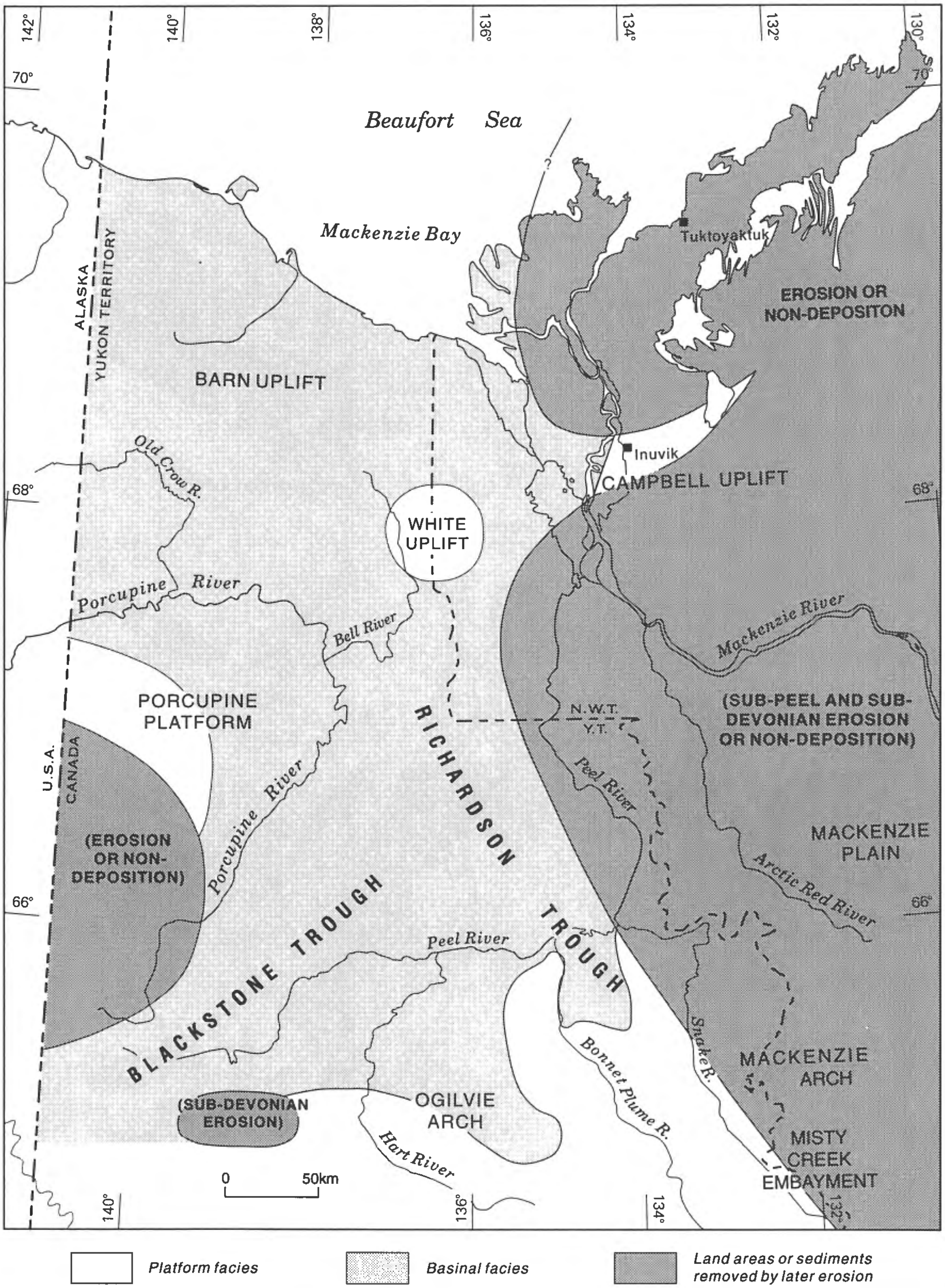

Figure 6.8. *Paleogeographic map, early Late Silurian time (Ludlow).*

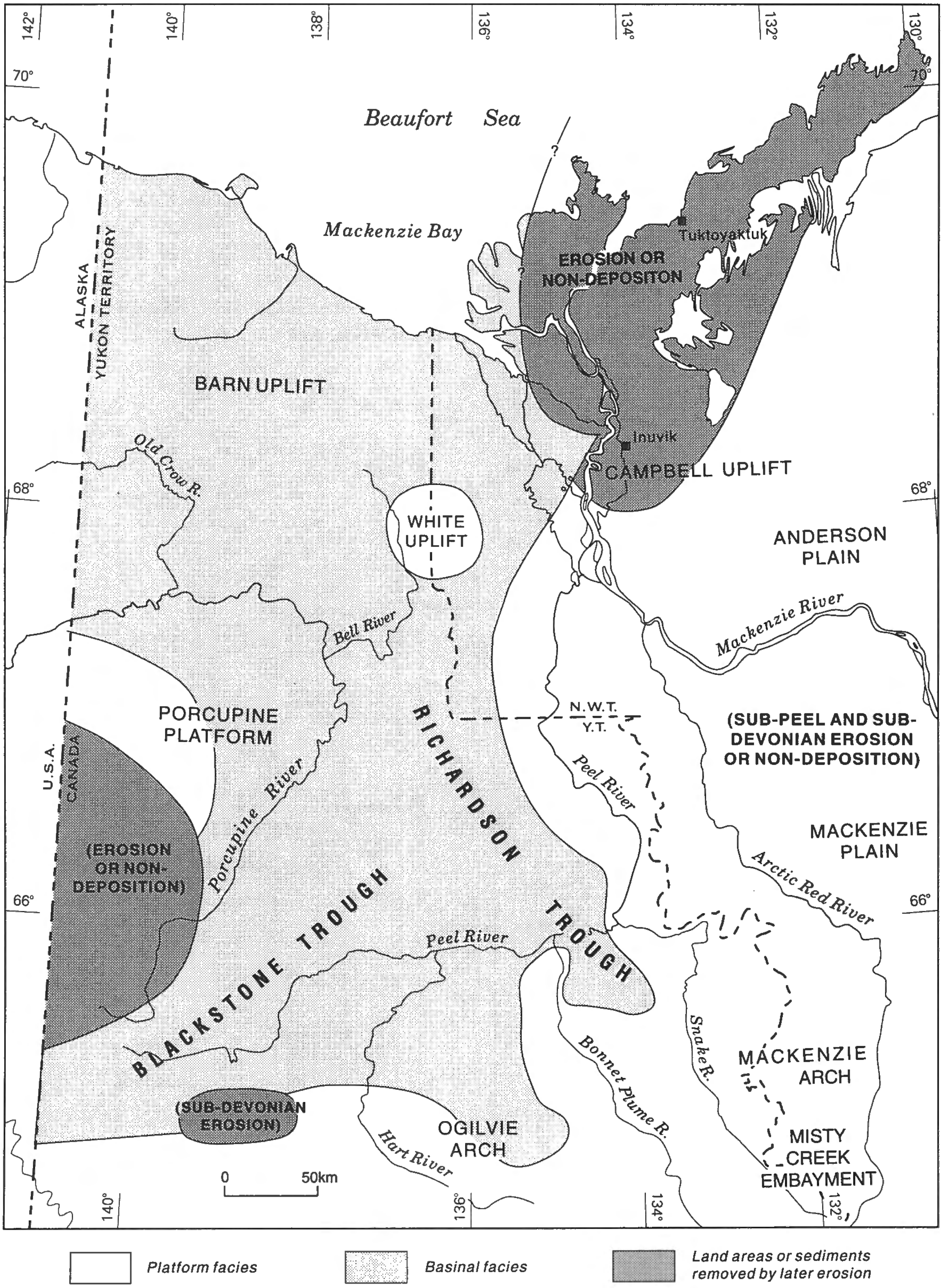

Figure 6.9. Paleogeographic map, late Late Silurian time (Pridoli).

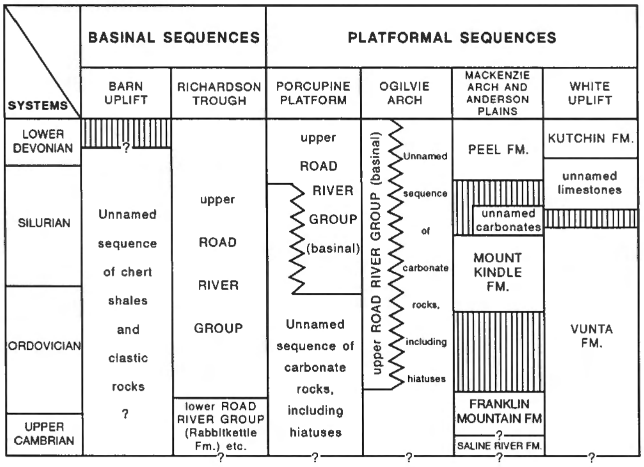

Figure 6.10. Simplified table of stratigraphic units.

1973, p. 285; Macqueen, 1974, p. 323; 1975, p. 293). Unconformities are known locally on the Ogilvie Arch and indicate intermittent uplift and erosion (Fig. 6.6). Map unit ЄD is overlain by different stratigraphic horizons of the Road River Group at many localities; at others, carbonate sedimentation continued well into the Devonian. At several places there are complex intertonguing relationships with slope and basinal facies of the Road River Group. These are especially well displayed on Royal Mountain (Fig. 6.1, loc. 37), at the adjacent Royal Creek Section (Fig. 6.1, loc. 6; Norford, 1964, p. 38-42; Norris, 1968, Pl. V; Macqueen, 1974; 1975, p. 323-325), in the Royal Creek headwaters area (Fig. 6.1, loc. 82; Green and Roddick, 1962, p. 6; Dooge and Raasch, 1967; Lenz, 1968, p. 605-606; Green, 1972, p. 33-36) and north of Pat

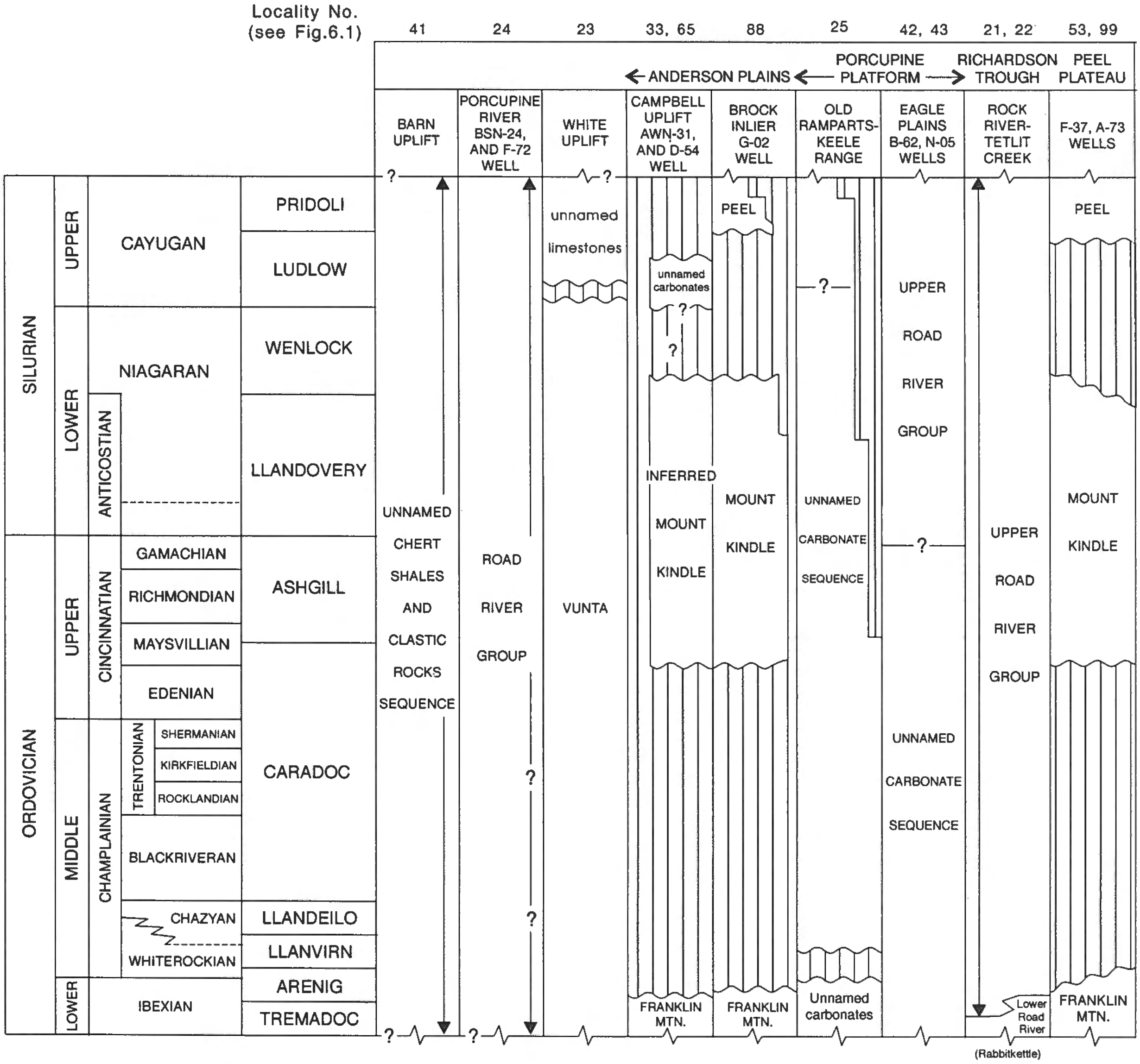

Figure 6.11. Stratigraphic correlations within northern Yukon and adjacent District of Mackenzie.

Lake (Fig. 6.1, loc. 9; Norford, 1964, p. 54). In Cambrian and Ordovician time, the Illtyd Range carbonate bank (Fig. 6.15) extended south to Royal Mountain and adjacent Wind River and was probably continuous with the Ogilvie Arch carbonate bank. However, during the Silurian the two banks were separated by deeper water with basinal sediments. Micritic and pelletal limestones indicate deposition in shallow water and are known both from the carbonate banks and from derived material within the Road River Group. Evidence of intertidal or supratidal exposure is conspicuously lacking in the Illtyd Range (Fig. 6.1, loc. 5) which is the only area where detailed sedimentological studies have been made (Macqueen, 1975, p. 293).

Porcupine Platform

This area, from the Tatonduk River north to the Porcupine River and from the Richardson Trough west into Alaska, was predominantly a carbonate regime during the early Paleozoic, but above the Cambrian, the stratigraphic thicknesses are considerably less than those on the Ogilvie Arch. Abrupt facies changes into coeval basinal sediments are documented in the south (Brabb, 1967; Churkin and Brabb, 1968) and are probably present in the subsurface of the Eagle Plain to the east (Moorehouse, 1966; Martin, 1973). There may have been similar changes in the north near Dave Lord Uplift and north of the Keele Range, but outcrops are sparse in these virtually unglaciated

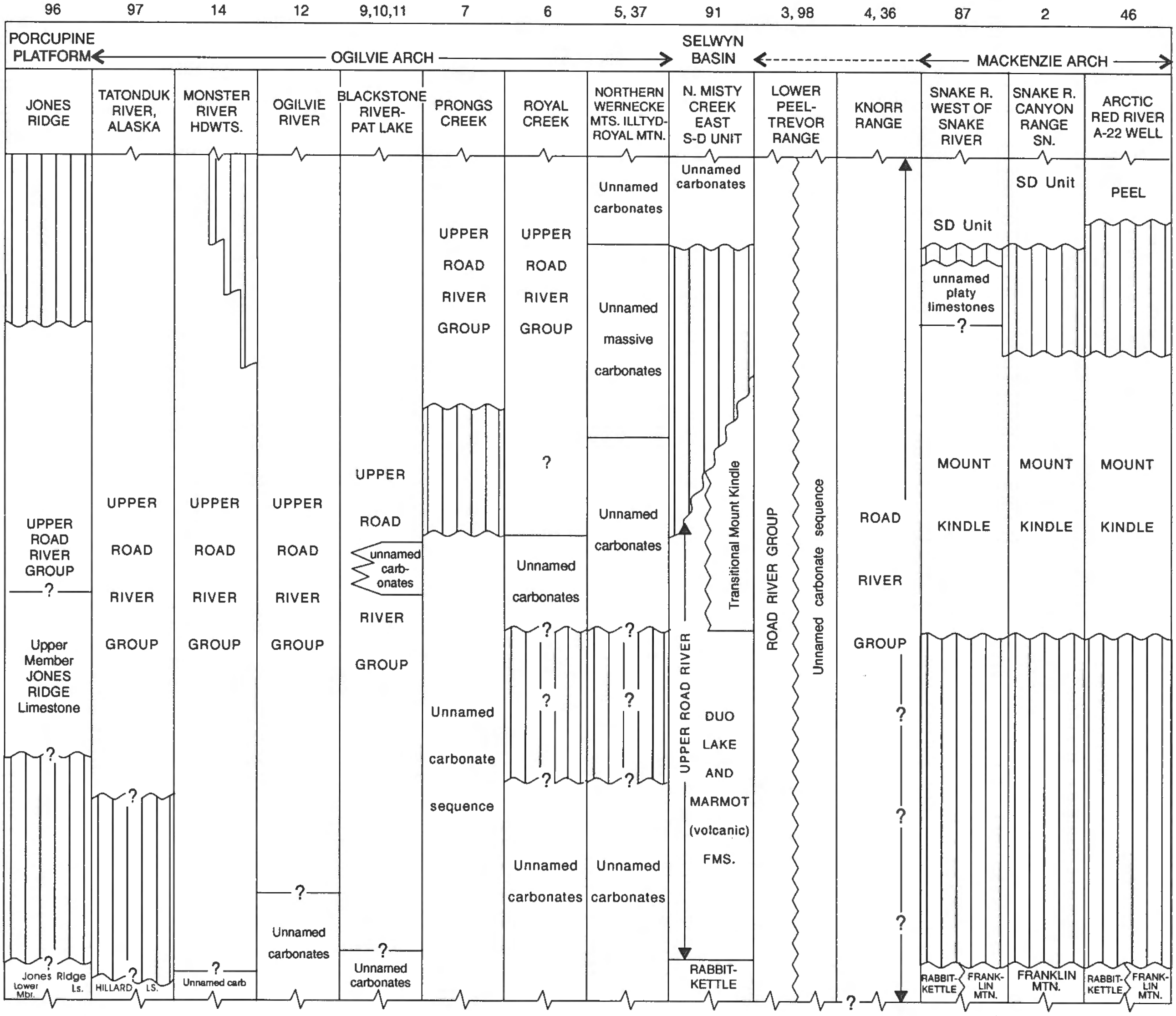

Figure 6.11. (cont'd).

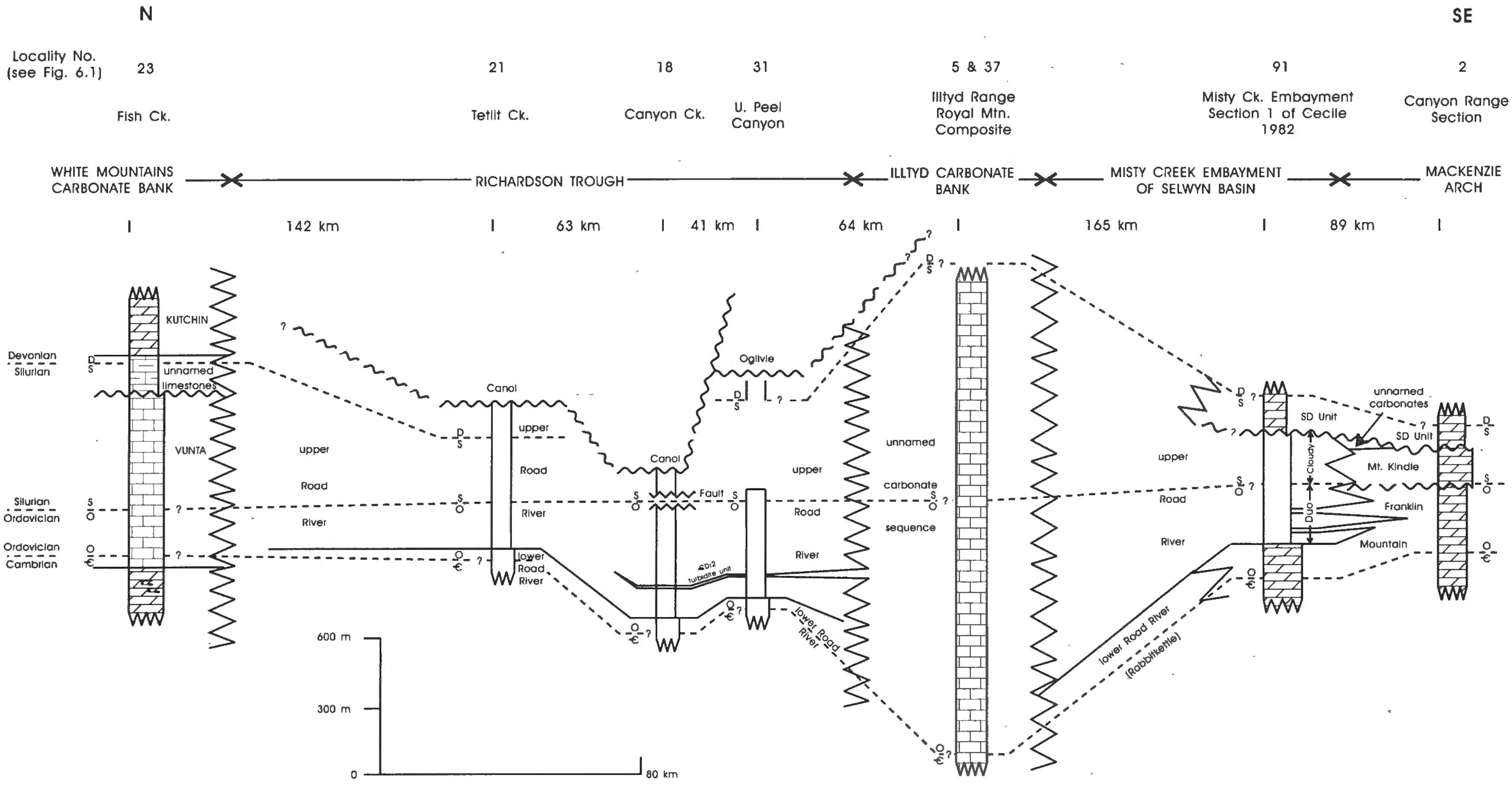

Figure 6.12. *Schematic cross-section, White Uplift to Mackenzie Arch. Details of stratigraphic sections are presented in Norford (1964) except for #31 (Jackson and Lenz, 1962), #37 (Macqueen, 1975), and #91 (Cecile, 1982).*

Zonal Designate		Series	Age
* *Monograptus yukonensis*		Pragian	Early Devonian
* *Monograptus thomasi*			
* *Monograptus hercynicus*		Lochkovian	
* *Monograptus uniformis uniformis*			
* *Monograptus uniformis augustidens*		Pridoli	Late Silurian
* *Pristiograptus transgrediens*			
* *Monograptus bouceki*			
* *Pristiograptus chelmiensis*			
* *Pristiograptus bugensius*			
* *Monograptus formosus*			
* *Saetograptus lientwardinensis primus*		Ludlow	
* *Nilssonigraptus nilssoni*			
beds with *Pristiograptus etheringtoni*		Wenlock	Early Silurian
* *Monograptus testis-Cyrtograptus lungreni*			
beds with *Monograptus firmus nahanniensis*			
* *Cyrtograptus rigidus*			
beds with *Cyrtograptus* cf. *Cyrtograptus perneri*			
* *Cyrtograptus centrifugus*			
* *Cyrtograptus sakmaricus-Cyrtograptus laqueus*		Upper Llandovery	
* *Monograptus spiralis*			
* *Monograptus turriculatus*			
* *Monograptus sedgwicki*			
* *Monograptus convolutus*		Middle Llandovery	
* *Monograptus gregarius*	*Monograptus argenteus* *Diplograptus magnus*? *Monograptus triangulatus*		
* *Monograptus cyphus*		Lower Llandovery	
* *Monograptus acinaces*			
* *Atavograptus atavus*			
* *Orthograptus acuminatus*			
* *Glyptograptus persculptus*?			
Lack of faunas indicating the Kazakhstanian *Climacograptus extraordinarius* Zone or the largely coeval Chinese *Paraorthograptus uniformis* and *Diplograptus bohemicus* zones.			
* *Pacificograptus pacificus*		Ashgill	Late Ordovician
* *Dicellograptus complanatus ornatus*			
* *Orthograptus quadrimucronatus*		Caradoc	
* *Orthograptus amplexicaulis*			
uncertain interval			
* *Climacograptus bicornis*		Llandeilo	Middle Ordovician
* *Nemagraptus gracilis*			
* *Glyptograptus* cf. *Glyptograptus teretiusculus*		Llanvirn	
* *Paraglossograptus tentaculatus*		Arenig	Early Ordovician
* *Isograptus victoriae*	(*Oncograptus*) (*I.v. maximodivergens*) (*I.v. lunatus*)		
* *Didymograptus bifidus*			
* *Tetragraptus fruticosus*			
* *Tetragraptus approximatus*	(3 & 4 branched) (4 branched)		
* *Adelograptus antiquus*		Tremadoc	
* *Clonograptus aureus*			
* *Anisograptus richardsoni*			
* *Staurograptus tenuis*			
uncertain interval equivalent to *Rhabdinopora flabelliformis* Zone in eastern Canada			

*Specific zones recognized within northern Yukon.

Sources: Barnes et al., 1981; Bjerreskov, 1975; Jackson, 1974, 1975; Jackson and Lenz, 1962; Jackson et al., 1978; Lenz, 1979a, 1982a; Lenz and McCracken, 1982; McCracken and Lenz, 1987; Rickards, 1970; Lenz and Chen, 1985.

Figure 6.13. *Graptolite zones, northwestern Canada.*

regions and much of the present surface is underlain by Precambrian and Cambrian rocks. Throughout the area, carbonate rocks continue from the upper Upper Cambrian into the Ordovician but are succeeded by basinal sediments of the Road River Group, within the Ordovician at most localities, within the Silurian at others and perhaps within the Lower Devonian at some localities within the Keele Range (Fig. 6.1, loc. 17; Cairnes, 1914; Norford, 1964; Lenz, 1972; Dean, 1973). Much of the record of Ordovician and Silurian time is missing, particularly in the southern part of the Porcupine Platform where a sub-Devonian uncon-

Figure 6.14. Massive Upper Ordovician carbonates (bedding almost vertical) at the gate of the canyon at the base of Prongs Creek Section (Fig. 6.1, loc. 7). GSC photo 133797.

Figure 6.15. Massive resistant Silurian carbonates, Unit 3 of South Illtyd Range Section (Fig. 6.1, loc. 5). The photograph shows about 200 m of section. GSC photo 133794.

formity cuts into strata as low as Middle Ordovician near Mt. Burgess (Fig. 6.4).

In the southwest, at the Yukon/Alaska border (Fig. 6.1, loc. 96), the Jones Ridge Limestone is a thick (about 900 m at its type section) Lower Cambrian to low Lower Ordovician carbonate succession, capped disconformably with a very thin (about 18 m) Upper Ordovician component. Above are poorly exposed argillaceous rocks of the Road River Group (6.4 m thick) that are known to be Upper Ordovician in the midpart and Lower Silurian (Wenlock) at the top (Ross and Dutro, 1966; Brabb, 1967; Churkin and Brabb, 1968; Potter et al., 1980; Barnes et al., 1981, column 18; Blodgett et al., 1984). At Jones Ridge, the Devonian Ogilvie Formation (Emsian at its base) disconformably overlies these Lower Silurian Road River rocks. A few kilometres to the west, graptolites of the Lower Silurian *Monograptus spiralis* Zone are present in an outcrop of the Road River (R.B. Blodgett, pers. comm., 1984) that represents beds not exposed at Jones Ridge itself. At the headwaters of Tindir Creek (Fig. 6.1, loc. 89, about 18 km northeast of Jones Ridge), an incomplete and undated stratigraphic section of the lower part of the Jones Ridge Limestone is 418 m thick. To the east, at the headwaters of Tatonduk River (Fig. 6.1, loc. 15), about 335 m of poorly dated dolomites and shallow water limestones (some pelletoidal) intervene between Precambrian rocks and Middle Ordovician Road River Group. At Mount Burgess (Fig. 6.1, loc. 16), at least 1100 m of Cambrian to Middle Ordovician carbonates underlie a sub-Devonian unconformity but probably most of these rocks are Cambrian.

Farther north, in the Keele Range east of Salmon Fork River (Fig. 6.1, loc. 38), a poorly known succession of carbonates is estimated to be 900 m thick and has Early (Arenig) and Middle (Llanvirn) Ordovician ages documented from limestones in the upper part (Dean, 1973). Conodonts of late Middle and Late Ordovician age have been identified nearby (GSC loc. C-51511, C.R. Barnes, pers. comm., 1978). Northwest of Blue Fish Lake (Fig. 6.1, loc. 17), a stratigraphic section of dolomites (about 180 m thick) is dated as Late Silurian in its basal part. In adjacent Alaska, Middle Ordovician (Caradoc) and Early Silurian (Wenlock) ages have been reported from discontinuous outcrops of carbonates in the Porcupine River–Salmontrout River area (Churkin and Brabb, 1968, p. 234-237; Churkin, 1973, p. 13-17). Late Silurian and Early Devonian graptolites are present in overlying shales. Isolated outcrops of poorly dated carbonates are widespread in the Keele Range and in Dave Lord Uplift. The latter feature extends northeastward to the Porcupine River (Fig. 6.1, loc. 24) where conglomerates have been reported from outcrops in the bed of the river (Lenz, 1972, p. 361; McGill, 1973). Lenz (1972) has dated corals from limestone boulders in the conglomerates as probably Late Ordovician. Topographically above the conglomerates, the adjacent banks of the river have outcrops of very steeply dipping Upper Silurian (Pridoli) and Lower Devonian shales and cherts of the Road River Group below flat-lying Cretaceous rocks (Fig. 6.16; Norford, 1964).

The Westcoast et al. North Porcupine Y.T. F-72 well (Fig. 6.1, loc. 81) is 8 km east-southeast of the outcrops on Porcupine River (Fig. 6.1, loc. 24). The well penetrates at least 1350 m of shales referred to the Road River Group by Pugh (1983). Palynomorphs from the upper 500 m have been dated as Early to Middle Devonian, and those from a stratigraphic interval 60 to 90 m lower, as Ordovician or Silurian (Pugh, 1983). At the outcrop locality, the exposed 86 m of Road River Group are dated as Pridoli, Lochkovian, and Pragian. The basal 790 m in the well probably represent most of Ordovician and Silurian time. The conglomerates in the bed of the river may represent a debris flow with material transported eastward from the margin of the Porcupine Platform.

Figure 6.16. *Angular unconformity at Porcupine River Section (Fig. 6.1, loc. 24; Norford, 1964, p. 120). Nearly horizontal (stick parallels bedding) Lower Cretaceous Sharp Mountain Formation rests on almost vertical Lower Devonian Road River Group, with a weathered zone. GSC photo 133835.*

Southeast from Dave Lord Uplift, the Porcupine Platform is documented by Upper Ordovician limestones present in the subsurface of the Eagle Plain (Fig. 6.1, locs. 27, 43, 42) below Lower Silurian (Llandovery) Road River Group in the Eagle Plains No. 1, North Cath B-62, and South Tuttle N-05 wells (Moorehouse, 1966; Norford, 1972, 1973a; Martin, 1973, p. 283-286). The drilled thicknesses of the Cambrian-Ordovician carbonate unit in these three wells exceed 760 m, 240 m and 640 m respectively without penetrating below the unit (Department of Indian and Northern Affairs, 1982). Drilled thicknesses of the overlying Road River Group are reported as 575 m, 453 m, and 248 m at the same wells (Martin, 1973, p. 283-286).

Studies by Pugh (1983) have attempted to recognize carbonate stratigraphic units from the Mackenzie Mountains within regions west of the Richardson Trough, deducing equivalencies through the Road River Group within the trough. In Eagle Plain, Pugh indicated the presence of the Franklin Mountain Formation, a Mount Kindle-Road River transitional unit, and the Peel Formation. These units cannot be demonstrated to have lithological continuity with the succession in the Mackenzie Mountains, neither through the intervening Road River sediments of the Richardson Trough, nor southward and eastward through the thick carbonate succession of the Ogilvie Mountains, the Wernecke Mountains, and the Illtyd Range. In addition, Late Ordovician faunas are known from strata in the subsurface of the Eagle Plain that Pugh (1983, p. 17, D-77, N-05, and N-49 wells) placed within the Franklin Mountain Formation. These faunas are significantly younger than the youngest faunas (Early and possibly Middle Ordovician) documented in the Mackenzie Mountains outcrops and in the adjacent subsurface. The present text uses an informal nomenclature for the carbonates west of the Richardson Trough.

White Uplift

This isolated bank (Fig. 6.1, loc. 23) of carbonate sediments is built on a foundation of Cambrian dolomitic breccias and dolomites. The resistant rocks of the Vunta Formation (about 565 m thick) probably represent all of Early Ordovician to mid-Early Silurian (late Llandovery) time but macrofossils are rare and biostratigraphic control has not been established.

Essentially coeval basinal facies were present to the west (Barn Uplift; Fig. 6.1, loc. 41), southwest (F–72 well; Fig. 6.1, loc. 81), south (Richardson Trough), and east (K–35, F–38 wells; Fig. 6.1, locs. 63, 64). The Vunta rocks indicate shallow-water deposition and include pelletoidal and micritic limestones. The top of the Vunta is at an abrupt unconformity (Norris, 1985, Section 47) below unnamed carbonates that include Upper Silurian (Pridoli and perhaps Ludlow) strata and probably represent continuous deposition into the Devonian. These carbonates thin drastically (from about 203 m to 33 m thick) within 16 km, thus indicating a probable unconformable contact with the overlying Kutchin Formation (top part mid-Emsian).

Campbell Uplift

On the east side (Fig. 6.1, loc. 33) of the Mackenzie Delta, carbonate rocks of undetermined thickness overlie Proterozoic and possibly Cambrian rocks. Norris (1967, p. 243–266; pers. comm, 1985) reported about 215 m of these carbonates beneath the Cranswick Formation (Emsian and Eifelian). *Atrypoidea* is present in the upper part of these beds, most of which are probably Upper Silurian. The rocks are mostly micritic limestones that weather grey and brownish grey but there are subordinate dolomites. Nineteen kilometres northwest of Norris's section, the Inuvik D–54 well (Fig. 6.1, loc. 65) contains about 850 m of carbonates which Pugh (1983, p. 76) assigned to the Franklin Mountain Formation. In the subsurface of Anderson Plain, 120 km to the east, MacKenzie (1974) and Pugh (1983) have studied the almost continuously cored Tenlen Lake A–73 well (Fig. 6.1, loc. 99). Rocks assigned to the Devonian Taksieta Formation overlie the Peel Formation (230 m thick) which is probably partly Upper Silurian but is lithologically very different from the upper rocks at Campbell Lake. In the well, the Peel Formation overlies the Mount Kindle Formation with probable unconformity and the Mount Kindle also lithologically does not resemble the Campbell Lake rocks. Similarly, the Vunta Formation (Ordovician to Upper Silurian, Ludlow) is lithologically dissimilar at the White Uplift, 115 km west of the Campbell Uplift. Correlation of the Campbell Lake Silurian rocks is puzzling, they could be equivalent to the unnamed carbonate unit above the Vunta Formation in the White Uplift. Both units may be facies equivalents of the Peel Formation or they may be older and missing from the A–73 well because of erosion at an unconformity beneath the Peel Formation. The interval is not reported from the nearby D–54 well, where a sub-Devonian unconformity is interpreted to rest directly on Ordovician rocks (Pugh, 1983, p. 16).

STRATIGRAPHY - BASINAL FACIES

Richardson and Blackstone troughs

Originally described in the Richardson Mountains (Jackson and Lenz, 1962) as rocks that later were shown to range from the Upper Cambrian to Middle Devonian, the term Road River Formation has been used throughout the northern Cordillera (Figs. 6.10–6.12). Promotion to group status has been suggested (Norford, 1979), and locally the sequence has been subdivided into formations (Norris, 1981a, b; 1982a, b, c; Cecile, 1982; pers. comm., 1990). Current use of Road River Group varies between geologists but a widespread practice is to use the name for gross recognition of all upper Lower Cambrian to Devonian basinal facies in the northern Cordillera. Deposition was in moderate to relatively deep water, with a great diversity of rock types: limy shales, cherts, argillaceous limestones, limestones, shales, dolomites, debris flows, turbidites and calcarenites (Figs. 6.17–6.22). Volcanic rocks are common at some stratigraphic horizons in the Selwyn Basin of the central Yukon, including just to the south of the Ogilvie Arch (Roots, 1988) and in the Kechika Trough of northern British Columbia, but none have been reported from the northern Yukon. However Innis (1980, p. 93–94) has reported micrites containing minute feldspar crystals and possible glass fragments that could represent volcanic ash as a constituent.

In the Richardson Trough, parts of the Road River Group represent virtually continuous deposition through Ordovician and Silurian time. However Lenz and McCracken (1982) have commented that the

Figure 6.17. *Shales and limestones of the Middle Ordovician Road River Group, Monster River Headwaters Section (Fig. 6.1, loc. 14). The figure is at Unit 7 of the section. GSC photo 133844.*

Figure 6.18. *Turbidite beds within the Middle Devonian Road River Group, Royal Creek Section (Fig. 6.1, loc. 6). The figure (Uldis Upitis) is near the base of Unit 7 of the section. ISPG photo 2115–1b.*

Figure 6.20. *Transported breccia (upper part of photograph) overlying contorted mudstones and shales, Middle Ordovician Road River Group, Tetlit Creek Section (Fig. 6.1, loc. 21) at 253 m. GSC photo 133811.*

Figure 6.19. *Basal surface of a turbidite bed, Lower Ordovician ЄDR2 Unit of the Road River Group. The limestone sharpstones (hammer for scale) are in a large fallen block in the Canyon Creek Section (Fig. 6.1, loc. 18). The unit is 4.6 m thick (Norford, 1964, p. 89). ISPG photo 2115–1a.*

Figure 6.21. *Transported limestone cobbles in shale matrix, Middle Ordovician Road River Group, Tetlit Creek Section (Fig. 6.1, loc. 21) at 312 m. GSC photo 133814, six-inch ruler for scale.*

uppermost Ordovician *extraordinarius* Zone and the basal Silurian *persculptus* Zone are not documented at Peel River (Fig. 6.1, loc. 31) where a 30 cm interval separates the younger *acuminatus* Zone from the high Ordovician *pacificus* Zone (see Fig. 6.13 for zonal sequence). The same authors report the *persculptus* Zone at other localities in the Richardson Trough. The Kazakhstanian *extraordinarius* Zone is not known in western or northern North America. Lenz and McCracken (1982) have speculated that this may reflect a hiatus or a change of sedimentary regime caused by a drop in sea level, both corresponding to a regression reflecting a major glaciation in Gondwanaland. However no evidence of discontinuity or erosion has been described from the Richardson Trough.

The Road River Group has complex facies relationships with the coeval limestones and dolomites of the adjacent banks and platforms. There is a general trend for the Road River Group to encroach progressively onto the carbonate banks with time, perhaps as a result of rising sea level. The carbonate banks shed

Figure 6.22. Folded shales and limestones, Lower Silurian Road River Group, tributary of Prongs Creek (Fig. 6.1, loc. 7; Norford, 1964, p. 43). The dead tree is about 1.5 m high. GSC photo 133796.

debris flows and turbidites. Many of these are very thin, but very thick beds extend far out into the basinal facies (Peel River, Canyon Creek, Noisy Creek; Cook and Mullins, 1983). In the Eagle River, Trail River, Wind River, and Hart River map areas, Norris (1981a, b; 1982b, c) has mapped a particularly thick bed as a unit (ЄDr2) within the Road River Group and mapped it for 70 km north–northwest from near Deception Mountain to Eagle River. At both Canyon Creek and Peel River (Fig 6.1, locs. 18, 31) the bed is documented to be within the *Adelograptus antiquus* Zone of the Lower Ordovician (Tremadoc). At Canyon Creek it is 6 m thick, boulder-sized limestone conglomerate at the base, grading up to pebble conglomerate in the upper part (Fig. 6.19; Norford, 1964, p. 89); and at Peel River it is 7 m thick (Jackson, 1974, p. 57). For most of its course this turbidity current deposit probably ran northward along the axial region of the Richardson Trough, from a source near Deception Mountain or near the Illtyd Range. If so, its distribution indicates that in the Early Ordovician the axial region of the Richardson Trough was on the west side of the present Richardson Mountains.

The thickness of the original lower member (Jackson and Lenz, 1962; Norford, 1964, p. 3-4; other authors have included subjacent units within the Road River) is not well documented but may be 1800 m. Trilobites and conodonts indicate that the member is virtually entirely Upper Cambrian, with Tremadocian graptolites from the top beds of some localities. The rocks consist of thin to medium bedded micritic limestones and argillaceous limestones with very minor limy shales. The rocks have many similarities with those of the Rabbitkettle Formation of the Selwyn Basin (Cecile, 1982, p. 12–14). Syndepositional slumping is present, as are rare limestone pebble-conglomerates and layers with fragmentary shelly fossils that are assumed to have been transported. The sedimentary environment is interpreted as a trough of moderate depth with adjacent slopes.

The upper member (about 780 m thick) of the Road River Group is a very varied assemblage of limy shales, argillaceous limestones, cherts, limestones (micrites, calcisiltites, calcarenites, some pelletoidal limestone), shales, dolomites, and conglomerates (Norford, 1964; Innis, 1980). Syndepositional slumping is common (Fig. 6.20). Many of the cherts are diagenetically silicified limestones of various types (Innis, 1980). Debris flows and turbidites are prominent (Fig. 6.18) and in the Canyon Creek section probably amount to more than 15 per cent of the Ordovician part of the group, with the thin beds being much more common and volumetrically more important than the spectacular thick units (Norford, 1964, p. 4, 5). Locally, Upper Silurian, orange weathering siltstones and mudstones are prominent within the Road River Group and similar rocks are present at similar horizons within the Road River of the Selwyn Basin of central Yukon, and of the Kechika Trough of northern British Columbia. The upper part of the Road River Group extends from Lower Ordovician (lower Tremadoc) to Middle Devonian. The contact with the lower member seems to be diachronous within the Tremadoc. The upper contact, in many places, is an unconformity but in others (Prongs Creek, Royal Creek) it appears to be conformable with younger Devonian basinal rocks.

Barn Uplift

In the northernmost Yukon (Fig. 6.1, locs. 41, 90), an assemblage of basinal rocks is coeval with much of the Road River Group but is lithologically different enough to warrant separate terminology (Figs. 6.10, 6.11; Cecile, 1988). Exposures are limited, discontinuous and structurally complex; thicknesses are not known and the present knowledge is inadequate for new formal nomenclature. Red and green cherty argillites, shales and phyllites, conglomerates, quartz sandstones and minor limestones may be Cambrian, and the presence of *Oldhamia* in parts of the succession indicates an Early Cambrian age. Apparently these rocks are overlain by dark grey cherts, shales, limestones and sandstones of Ordovician and Silurian age. The succession has similarities to those of the western parts of the Selwyn Basin (Cecile, 1988). Various younger unconformities locally place Carboniferous, Jurassic and Lower Cretaceous rocks on top of the assemblage. The rocks have been termed Neruokpuk Formation (Norris et al., 1963; Lenz and Perry, 1972) but their equivalence to the largely Precambrian Neruokpuk of eastern Alaska has not been substantiated. Graptolites from the upper part of the assemblage demonstrate Early and Middle Ordovician and Early and Late Silurian ages. The assemblage extends northwestward from Barn Uplift to Firth River and offshore into the continental shelf of the Beaufort Sea (Fig. 6.1, locs. 41, 90, 26).

UNCONFORMITIES

Despite the sparseness of detailed studies of stratigraphic sections in the Lower Paleozoic carbonate successions, a number of unconformities have been detected. Probably most of the successions on the carbonate banks include hiatuses that reflect changes of sea level or local pulses of uplift.

In the westernmost Mackenzie Mountains, essentially all of the Middle Ordovician is missing below the Mount Kindle Formation that rests with prominent disconformity on Lower Ordovician beds of the Franklin Mountain Formation. Regionally the Franklin Mountain Formation unconformably overlies Precambrian rocks. The sub-Peel contact appears to be disconformable (Norris, 1968, p. 20; Broad and Lenz, 1972, p. 415), perhaps corresponding to the sub-Delorme unconformity to the southeast in the Mackenzie Platform (Norford and Macqueen, 1975, p. 16).

In the Knorr Range (Fig. 6.1, loc. 4), west of the Mackenzie Mountains, Lenz (1972, p. 325, 328, 358, loc. 20; 1982c, p. 1921) reported that a narrow Bonnett Plume High was emergent throughout Ordovician and Silurian time. The concept is based on the succession at a single locality but no stratigraphic details have been published. Earlier and subsequent works have demonstrated the presence of the Road River Group and of a transitional Mount Kindle Formation a few kilometres away (Norford, 1964, p. 30–33; Fritz, 1974, fig. 1, loc. 10; Macqueen, 1974, p. 325; Norris and Hopkins, 1977, p. 9, 11; Cecile, 1982, p. 28) with faunal documentation of Middle Ordovician, Lower Silurian, Upper Silurian and Lower Devonian horizons. Norris (1982b; Norris and Hopkins, 1977, p. 4, 5) has mapped Road River and transitional Mount Kindle strata overstepping Lower Cambrian limestones to rest directly on Precambrian limestones, dolomites and shales. There would seem to be an unconformity below the transitional Mount Kindle and approximately coeval Road River, corresponding to the similar unconformity in the Mackenzie Mountains. As in the Mackenzie Mountains, the probable absence of rocks representing much of the Lower and Middle Ordovician could be caused either by erosion of such rocks prior to the sub-Mount Kindle unconformity, or by non-deposition at a land area.

Farther west, the Illtyd Range (Fig. 6.1, loc. 5) seems to have been the site of continuous sedimentation. At the northeastern margin of the Ogilvie Arch carbonate bank, lowermost Silurian rocks are absent at Prongs Creek (Fig. 6.1, loc. 7) where the basal Road River Group is Upper Llandovery (*turriculatus* Zone) and rests directly on Upper Ordovician carbonates. In northeastern Dawson map area (Figs. 6.4–6.9; Green, 1972), the axial part of the arch, Devonian rocks overstep Middle Ordovician and Silurian Road River Group to rest directly on carbonates that are probably no younger than Early Ordovician. Along the Yukon/Alaska border at Jones Ridge (Fig. 6.1, loc. 96), at the southern limit of the Porcupine Platform, a disconformity separates the two members of the Jones Ridge Limestone and represents most of Early and Middle Ordovician time (Barnes et al., 1981, Column 18). In adjacent basinal facies, Brabb (1967, fig. 13) indicated that high Arenig rocks rest unconformably on Tremadocian and older horizons. Also, over most of the Porcupine Platform, Devonian rocks rest disconformably on various horizons within the Lower, Middle and Upper Ordovician, with Silurian rocks being preserved only in the northern part. In the Keele Range a hiatus has been interpreted within the high Lower to low Middle Ordovician interval (high Arenig to low Llanvirn; Dean, 1973, p. 25).

Thus, despite the sparseness of detailed stratigraphic sections, there is evidence of a number of unconformities within the carbonate sequence, representing hiatuses followed by transgressions at about Llanvirn, very late Caradoc, Middle Llandovery and especially early Pridoli times (Fig. 6.11). All the banks were not affected by all the trangressions but the records of some may have been removed locally by later erosion prior to a widespread Emsian (Early Devonian) transgression.

In the basinal facies there is little evidence of stratigraphic or biostratigraphic breaks. Lenz and McCracken (1982, p. 1319) have commented on the lack of evidence for the Asian uppermost Ordovician *extraordinarius* Zone in the Road River Group and Innis (1980) and Lenz (1982c, p. 1923) have presented evidence indicating some shallowing of the Richardson Trough in late Early Silurian (Wenlock) time, allowing for bioturbation of the basinal sediments.

Overall, there is a record of irregular but progressive encroachment of basinal sediments onto the carbonate banks. Either fluctuations in sea level resulted in the regressions and transgressions, or local uplifts caused local regressions, with transgressions following naturally with a general rise in sea level. Although their stratigraphies are not known in detail, disconformities are rare within the very thick shallow-water successions in the Illtyd Range and the White Mountains. An exception is the unconformity above the Vunta Formation at the latter locality, with the Wenlock and lower Ludlow essentially absent. These localities are at the south and north ends of the Richardson Trough respectively, which might have been the site of maximum and almost continuous subsidence. The great thicknesses of the carbonate banks at these two localities may indicate large amounts of subsidence similar to the trough itself but with rapid accumulation of shallow-water limestones maintaining the banks close to sea level. This reasoning would suggest that most of the unconformities recognized on the other carbonate banks are secondary results of transgressions after local uplifts.

BIOSTRATIGRAPHY AND PALEONTOLOGY

Except for the graptolite sequences collected by Jackson, Lenz and Norford, there has been no systematic sampling of the Ordovician and Silurian faunas of the northern Yukon. The conodont and acritarch assemblages are virtually unknown and knowledge of the macrofaunas of the carbonate banks is very erratic. However, detailed Upper Silurian stratigraphic sections have been studied and collected near the edge of the Ogilvie Arch carbonate bank at Prongs Creek and at the headwaters of Royal Creek, just south of the studied region, and the conodont, coral and brachiopod faunas of these sections have been outlined (Jackson et al., 1978).

Taxonomic studies and biostratigraphic contributions that illustrate brachiopods, conodonts, corals, fish, ostracodes and trilobites from the northern Yukon include:

Broad and Lenz, 1972
Copeland, 1966
Dean, 1973
Dineley, 1965
Jackson, Lenz and Pedder, 1978
Kobayashi, 1936
Lenz, 1970, 1977a, b, 1982b
Lenz and Churkin, 1966
Lenz and McCracken, 1982
Ludvigsen, 1980
McCracken and Lenz, 1987
Norford, 1973b
Pedder, 1971, 1976
Pedder and McLean, 1976
Raasch, Norford and Wilson, 1961

Much more is known concerning the sequence of graptolite faunas, largely through the efforts of Lenz and Jackson. Almost all of the graptolite zones known from the Cordillera (Fig. 6.13) have been documented from the northern Yukon. The exception is the Wenlock. Of the six intervals identified elsewhere in the Wenlock of the northern Cordillera, only three (*centrifugus, rigidus,* and *testis–lungreni* zones) have been reported from the northern Yukon. Lenz (1978, p. 624; 1980, p. 1076; 1982c, p. 1923) has commented that the Wenlock part of the Road River Group in the Richardson Trough is both poorly fossiliferous and bioturbated. He interprets the Wenlock as an interval of relatively shallow water, inclement to the preservation of graptolites. As previously noted, the Asian uppermost Ordovician *extraordinarius* Zone is absent, possibly due to a worldwide drop in sea level. A puzzling absence is the basal Ordovician *flabelliforme* Zone that has extensive world-wide distribution except that it has not yet been reported anywhere in western and northern North America. This zonal assemblage could be a cold water assemblage and therefore would not have developed in Ordovician equatorial regions. However, lower Tremadoc basinal facies are very rare in western and northern North America, other than in the Selwyn Basin and the Richardson Trough, and the very limited extent of collecting in both these areas is insufficient to completely rule out the presence of the *flabelliforme* Zone.

The detailed studies that have been completed (Dresbachian, Tremadoc, Llandovery, Ludlow, Pridoli, Lochkovian and Pragian faunas) indicate that the Road River Group presents one of the world's most complete sequences of graptolite faunas. Taxonomic studies and biostratigraphic contributions that illustrate graptolites from the northern Yukon include:

Berry and Norford, 1976
Jackson, 1964, 1973, 1974, 1975
Jackson and Lenz, 1963, 1969, 1972
Jackson, Lenz and Pedder, 1978
Lenz, 1977c, 1978, 1979b, 1982a, 1984, 1988a, b
Lenz and Chen, 1985
Lenz and Jackson, 1971
Lenz and McCracken, 1982
Lenz and Perry, 1972

ECONOMIC GEOLOGY

The setting is that of widespread potential petroleum source rocks in the basinal facies, bounded laterally by carbonate banks, complete with associated shelf edge deposits and debris flows. This is potentially attractive for petroleum exploration. However, conodonts illustrated by McCracken (Lenz and McCracken, 1982, Pls. 1, 2) from uppermost Ordovician and basal Silurian beds of the Road River Group at Blackstone River and Peel River all have conodont Colour Alteration Index values of 4 (G.S. Nowlan, pers. comm., 1983). Assuming maximum burial in Carboniferous time, this index indicates maximum temperatures of 180-190°C (following Epstein et al., 1977). These temperatures are too high for the retention of any oil generated in the sediments, and prospects for dry gas are marginal (Legall et al., 1982). Ordovician and Silurian rocks sampled at James River and Rock River by Cecile have conodont Colour Alteration Index values of 5 (G.S. Nowlan, pers. comm., 1983) that indicate even higher temperatures. Similar data have been reported by Link and Bustin (1989). Kerogen sampled from Road River rocks in the Richardson Trough and Eagle Plain is overmature (Link et al., 1989). Vuggy porosity is known to be present in Ordovician rocks of the Ogilvie Arch carbonate bank (at Royal Creek, Blackstone River, Ogilvie River and its headwaters, and Mount Burgess), but no bitumen was observed in outcrops during the 1962 field work. Vuggy porosity and pyrobitumen are reported from Ordovician carbonates capped with Road River shales in the subsurface of the Eagle Plain, but all four exploratory wells that penetrated below the Road River encountered water in the carbonates (Moorehouse, 1966, p. 12; Martin, 1973, p. 285).

No mineral showings were encountered during 1962 but the field studies were a rapid reconnaissance. Since then, lead, zinc, silver and barite have been reported from the western part of the Ogilvie Arch carbonate bank (Fig. 6.1, locs. 92, 93, 11, near Mount Skookum Jim, Mount Bouvette, Blackstone River; Norris, 1982a; Abbott, 1982) and zinc, barite and copper from the Road River Group near Rock, Road and Vittrekwa rivers (Fig. 6.1, locs. 22, 40, 72; Cecile et al., 1982). The 1962 field work did not include geochemical sampling of the Lower Paleozoic basinal facies of the northern Yukon. Later, samples from the Devonian part of the Road River Group at Royal Creek showed slightly higher than normal contents of Fe, Zn, Cu, Ni, and Sr (Macqueen, 1975, p. 298). Southeast of the Ogilvie Arch carbonate bank, geochemical studies have been carried out on the closely comparable Lower Paleozoic basinal facies of the Misty Creek Embayment of the Selwyn Basin (Cecile, 1982). There, veins with base metals are reported from carbonates of the Mount Kindle Formation and of the transitional Franklin Mountain Formation. Stratiform barite is known locally from Ordovician and Silurian horizons within the Road River Group (Duo Lake and Cloudy Formations). Slightly enriched levels of Zn, Cu, Ni, Co, Ag, Ba, Ti, Cr, Mg, Na, Ce, As, Sb, Cd, Sr, V, and organic carbon are recorded from shaly rocks of the Middle Ordovician Duo Lake Formation in the one stratigraphic section sampled for geochemical analysis (Goodfellow et al., 1980, p. 158–159; Cecile, 1982, p. 29–31). However, Middle Ordovician volcanic rocks are present within the Misty Creek Embayment (and as yet unknown from the northern Yukon) and the enrichment within the Duo Lake Formation may be related to this igneous activity (Goodfellow et al., 1980, p. 160).

Little is known of the mineral potential of the Richardson and Blackstone troughs but they and their adjacent carbonate banks provide a geological model that is encouraging for exploration for base metals. The setting is analagous to those of the Selwyn Basin in east–central Yukon and nearby District of Mackenzie and of the Kechika Trough in northern British Columbia. Very significant discoveries have been made in these two areas, with extensive strata-bound deposits in basinal facies, including the X–Y lead-zinc deposit in Lower Silurian beds of the Road River Group at Howards Pass (Morganti, 1979; Norford and Orchard, 1985).

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Appendix 6.1

Previously unpublished biostratigraphic data

Field no. and stratigraphy	Locality, fauna and age	GSC loc. no.
	Royal Creek Section	
	(Fig. 1, loc. 6; Norford, 1964, p. 38–42, 125, 126) 65°02′-04′N, 135°02′-10′W	
2007–2012 ft., Unit 4, Road River Group	cricoconarids *Dictyonema* sp. *Monograptus* sp.	53087
1989 ft., Unit 4, Road River Group	*Spirigerina* sp. (identified by A.W. Norris) *Monograptus telleri* Lenz and Jackson	53086
1961–1971 ft., Unit 4, Road River Group	*Monograptus telleri* Lenz and Jackson	53085
1906–1911 ft., Unit 3, Road River Group	cricoconarids undetermined brachiopod dendroid graptolites *Monograptus telleri* Lenz and Jackson	53084
1830–1835 ft., Unit 3, Road River Group	*Dictyonema* sp. *Monograptus* ex gr. *M. yukonensis* Jackson and Lenz	53083
1813–1814 ft., Unit 3, Road River Group	cricoconarids *Dictyonema* sp. *Monograptus yukonensis yukonensis* Jackson and Lenz	53082
1703–1705 ft., Unit 3, Road River Group	*Dictyonema* sp. Age: (53081–52087): Early Devonian, Pragian, *yukonensis* Zone, (D.E. Jackson and B.S. Norford)	53081
1165–1175 ft., Unit 1, unnamed carbonates	stromatoporoid solitary and favositid corals *Calapoecia* sp. *Catenipora* sp. Age: probably Late Ordovician	53080
MQY-15-58, about 1163–1170 ft., Unit 1, unnamed carbonates	*Panderodus* sp. *P. gracilis* Branson and Mehl Age: Middle to Late Ordovician (C.R. Barnes)	C-26721
MQY-15-57, about 1061–1071 ft., Unit 1, unnamed carbonates	*Appalachignathus* aff. *A. denticulatus* Bergström et al. *Drepanoistodus suberectus* Branson and Mehl *Panderodus*? sp. *Phragmodus* sp. *Plectodina* cf. *P. aculeata* Stauffer Age: probably middle Middle to early Late Ordovician, Blackriverian to early Maysvillian (C.R. Barnes)	C-26720

Field no. and stratigraphy	Locality, fauna and age	GSC loc. no.
MQY-15-56, about 874 ft., Unit 1, unnamed carbonates	*Eobelodina* cf. *E. occidentalis* Ethington and Schumacher *Trichonodella* sp. Age: early Middle Ordovician, Chazyan (C.R. Barnes)	C-26719
MQY-15-54, about 656 ft., Unit 1, unnamed carbonates	*Juanognathus variabilis* Serpagli *Prioniodus* cf. *P.* sp. C of MacTavish cf. *Rutterodus andinus* Serpagli *Scolopodus cornutiformis* Branson and Mehl *S. gracilis* Ethington and Clark Age: Early Ordovician, early Arenig, (C.R. Barnes)	C-26717
MQY-15-53, about 640-656 ft., Unit 1, unnamed carbonates	*Drepanodus* sp. *Paltodus* sp. Age: Probably Early Ordovician (C.R. Barnes)	C-26716
MQY-15-52, about 384-394 ft., Unit 1, unnamed carbonates	*Clavohamulus densus* Furnish *Paltodus variabilis* Furnish Age: Early Ordovician, late Tremadoc or possibly early Arenig (C.R. Barnes)	C-26715
	Campbell Lake Section	
	(Fig. 1, loc. 33; Norris, 1967, p. 260) 68°15'-17'N, 133°11'-17°W	
107 C2, 612.2-614.2 ft., unnamed carbonates	*Atrypoidea* sp. Age: Late Silurian	54978
	Canyon Ranges Section	
	(Fig. 1, loc. 2; Norford, 1964, p. 19-25, 123, 124) 65°28'-30'N, 132°57'-133°03'W	
2644 ft., Unit 18, Peel Formation, 207 ft., above Mount Kindle Formation	*Oulodus* sp. 3 of Uyeno (1981) *O.* cf. *O.* sp. 6 of Uyeno (1981) *Panderodus* sp. indeterminate nautlioids *Murchisonia*? sp. Age: Late Silurian, Ludlow, *siluricus* Zone to *latialata* Zone (T.T. Uyeno)	53153
	Knorr Range Section	
	(Fig. 1, loc. 36; MQ-10 of Macqueen, 1974) 64°24'N, 133°56'W	
MQY-10-15F, 351 m, Peel Formation	heterostracan fish fragments (identified by R. Thorsteinsson)	C-26678

Field no. and stratigraphy	Locality, fauna and age	GSC loc. no.
MQY-10-13F, 173 m, talus, unnamed carbonates	indeterminate gastropod *Favosites*? sp. aff. *Syringopora* sp. *Atrypoidea* sp. *Conchidium* (s.s.) sp. Age: Late Silurian, probably Ludlow or Pridoli	C-26676
MQY-10-11F, 159 m, unnamed carbonates	indeterminate gastropods *Protathyris* sp. cyathaspidid fish fragment (identified by R. Thorsteinsson) *Leperditia* cf. *L. scalaris* (Jones) (identified by M.J. Copeland) Age: Late Silurian, probably Pridoli	C-26674
MQY-10-6F, 72 m, talus, Mount Kindle Formation	indeterminate solitary corals *Cystihalysites* sp. *Favosites* 2 spp. Age: Silurian	C-26670
MQY-10-5F, 53-56 m, Mount Kindle Formation	indeterminate colonial rugose coral *Favosites* sp. *Multisolenia* sp. Age: Silurian, probably Llandovery	C-26669

South Illtyd Range Section

(Fig. 1, loc. 5; MQ-12 of Macqueen, 1974;
Section 5 of Norford, 1964, p. 34-37, 125)
65°14'N, 135°11'-14'W

Field no. and stratigraphy	Locality, fauna and age	GSC loc. no.
MQY-12-26F, 1900 ft., unnamed carbonates	*Atrypoidea* sp. Age: Late Silurian, Ludlow to Pridoli	C-26688

Wernecke Mountains, north of Wind River

(Fig. 1, loc. 30; Macqueen, 1975, p. 291)
65°03'N, 134°45'W

Field no. and stratigraphy	Locality, fauna and age	GSC loc. no.
MQY-13-27, 340-346 m, unnamed carbonates	*Acodus* cf. *A. oneotensis* Furnish *Oneotodus* sp. *Scolopodus gracilis* Ethington and Clark Age: early Arenig, Fauna D of Ethington and Clark, 1971 (C.R. Barnes)	C-26689

Field no. and stratigraphy	Locality, fauna and age	GSC loc. no.
	Wind River West Section (Fig. 1, loc. 28; Macqueen, 1975, p. 291-293) 65°08′N, 135°06′W	
MQY-14-48, 1019 m, unnamed carbonates	*Paracordylodus gracilis* Lindström *Prioniodus* sp. C of MacTavish Age: Early Ordovician, early Arenig (C.R. Barnes)	C-26711
MQY-14-47, 1005-1009 m, unnamed carbonates	*Bergstroemognathus extensus* Serpagli *Juanognathus variabilis* Serpagli *Oistodus lanceolatus* Pander *Paltodus* cf. *P.* sp. B of Ethington and Clark *Paracordylodus gracilis* Lindström *Prioniodus* sp. C of MacTavish *Scolopodus cornutiformis* Branson and Mehl *S. gracilis* Ethington and Clark *S. quadraplicatus* Branson and Mehl *Walliserodus australis* Serpagli Age: Early Ordovician, early Arenig (C.R. Barnes)	C-26710
MQY-14-45, 933-937 m, unnamed carbonates	*Clavohamulus densus* Furnish *Paltodus variabilis* Furnish *Scolopodus*? sp. Age: Early Ordovician, Late Tremadoc or possibly early Arenig, Fauna C or possibly D of Ethington and Clark (C.R. Barnes)	C-26708
MQY-14-43A, 44, 894-914 m, unnamed carbonates	*Acanthodus* sp. *Acodus* sp. A of Ethington and Clark *Acontiodus* sp. A of Ethington and Clark *Juanognathus* sp. *J. variabilis* Serpagli *Loxodus bransoni* Furnish *Oistodus* sp. *Paltodus* sp. *Scolopodus* cf. *S. cornutiformis* Branson and Mehl *S. gracilis* Ethington and Clark Age: Early Ordovician, Late Tremadoc or early Arenig, late Fauna C or D of Ethington and Clark (C.R. Barnes)	C-26707, C-26706
MQY-14-43, 851-853 m, unnamed carbonates	*Acontiodus* sp. *Juanognathus*? sp. Age: probably Early Ordovician (C.R. Barnes)	C-26705
MQY-14-41, 730-733 m, unnamed carbonates	*Acodus?* sp. Age: probably Early Ordovician (C.R. Barnes)	C-26703

Field no. and stratigraphy	Locality, fauna and age	GSC loc. no.
	Royal Mountain Section (Fig. 1, loc. 37; MQ-16 of Macqueen, 1974) 65°03′N, 135°05′W	
MQY-16-82F, 84F, 841 m, unnamed carbonates	''*Leperditia*'' *hisingeri egena*? Jones Age: Silurian, late Wenlock to early Pridoli (M.J. Copeland)	C-26745, C-26747
MQY-16-81F, 625 m, unnamed carbonates	''*Leperditia*quc; *phaseolus* (Hisinger) Age: Silurian, probably Wenlock (M.J. Copeland)	C-26744
MQY-16-76F, 439 m, unnamed carbonates	undetermined solitary coral and brachiopods *Favosites* sp. *Encrinurus* sp. *Goldillaenus* sp. phacopid trilobite Age: Silurian	C-26739
MQY-16-72F, 410 m, unnamed carbonates	indeterminate gastropod, brachiopod, corals *Favosites*? 2 spp. *Pentamerus* sp. Age: Silurian, probably Late Llandovery	C-26735
MQY-16-69F, 286 m, unnamed carbonates	echinoderm undetermined solitary coral *Favosites*? sp. *Eospirifer* sp. *Pentamerus* sp. Age: Silurian, probably Late Llandovery	C-26732
MQY-16-66F, 213-215 m, unnamed carbonates	*Favosites* sp. Age: Late Ordovician to Middle Devonian	C-26729
MQY-16-64F, 174-178 m, unnamed carbonates	streptelasmid coral *Bighornia* sp. *Calapoecia* sp. *Catenipora* sp. *Foerstephyllum*? sp. Age: Late Ordovician	C-26727
MQY-16-62F, 53 m, unnamed carbonates	bryozoan streptelasmid and favositid corals *Calapoecia*? sp. *Catenipora* sp. *Favosites* sp. *Palaeophyllum* sp. *Furcitella* sp. *Rhynchotrema* sp. *Strophomena* sp. Age: Late Ordovician	C-26725

Field no. and stratigraphy	Locality, fauna and age	GSC loc. no.
MQY-16-60F, 30 m, unnamed carbonates	*Trichonodella*? sp. Age: probably Middle or Late Ordovician (C.R. Barnes)	C-26723

Southwest of Komakuk Beach

(Fig. 1, loc. 26) 69°32.5′N, 140°19′W
photo A13231-70, coordinates +2.33x, -5.11y

Field no. and stratigraphy	Locality, fauna and age	GSC loc. no.
NC1173-1F, talus	*Monograptus* cf. *M. transgrediens praecipuus* (Pribyl) Age: Late Silurian, Pridoli, *chelmiensis* Zone to *transgrediens* Zone	C-41895

Fish Creek Section

(Fig. 1, loc. 23; Section 23 of Norford, 1964, p. 111-118, 135-137) 67°56′N, 136°31-40′W

Field no. and stratigraphy	Locality, fauna and age	GSC loc. no.
Kutchin Formation, 20 m (60 ft.) below top, 697 m (2291-2292 ft.) above top of Vunta Formation	*Amphipora* sp. stromatoporoids *Alveolites* sp. *Spongaria* sp. *Planetophyllum* sp. *Trypanopora* sp. Age: late Early Devonian, mid-Emsian (A.E.H. Pedder)	53211
unnamed carbonates, 185 m (608 ft.) above top of Vunta Formation	*Atrypoidea* sp. Age: probably latest Silurian, late Pridoli	53209
unnamed carbonates, 180 m (592 ft.) above top of Vunta Formation	echinoderm and gastropod fragments colonial rugose coral	53208
unnamed carbonates, 179 m (587 ft.) above top of Vunta Formation	*Atrypoidea* cf. *A. netserki* Jones *Ozarkodina remscheidensis remscheidensis* (Ziegler) Age: latest Silurian, late Pridoli (late Pridoli to mid-Lochkovian on conodonts, Uyeno; late Ludlow to Pridoli on brachiopods)	53207
unnamed carbonates, 168 m (552 ft.) above top of Vunta Formation	echinoderm fragments, bryozoan stromatoporoid solitary coral	53206
unnamed carbonates, 125 m (409 ft.) above top of Vunta Formation	stromatoporoid *Cystiphyllum* sp. *Favosites* sp. undetermined solitary and tabulate corals ?*Atrypoidea* sp. Age: probably Late Sulurian	53205

Field no. and stratigraphy	**Locality, fauna and age**	**GSC loc. no.**
unnamed carbonates, 121 m (399 ft.) above top of Vunta Formation	bryozoan colonial rugose coral	53204
unnamed carbonates, 102–103 m (337–340 ft.) above top of Vunta Formation	stromatoporoids solitary and tabulate corals	53203
unnamed carbonates, 66 m (218 ft.) above top of Vunta Formation	solitary and tabulate corals	53202
unnamed carbonates, 44 m (145 ft.) above top of Vunta Formation	*Herrmannina* sp. *Protathyris* sp. Age: Late Silurian, late Wenlock to Pridoli	53201
Vunta Formation, 11–12 m (37–39 ft.) below top	*Gibberella* aff. ?*G. maydeli* (Schmidt) *Leperditia* sp. (probably of the *hisingeri* group) Age: Early Silurian, possibly mid–Late Llandovery (Copeland)	53199
Vunta Formation, 24 m (78 ft.) below top	stromatoporoid solitary coral	54663
Vunta Formation, 35–38 m (116–126 ft.) below top	undetermined corals and brachiopods *Favosites* spp. *Leperditia hisingeri egena*? Jones *Yukopsis jobi* Copeland Age: Silurian, possibly Late Llandovery (Copeland)	53196–7
Vunta Formation, 64–70 m (210–228 ft.) below top	undetermined corals, brachiopods and stromatoporoid *Cystihalysites* sp. *Favosites* sp. *Multisolenia tortuosa* Fritz *Gibberella* cf. *G. jejuma* Abushik *Leperitia hisingeri egena*? Jones indeterminate leperditiid ostracodes Age: Silurian, Late Llandovery (Norford and Copeland)	53193–4
Vunta Formation, 153 m (503 ft.) below top	echinoderm and brachiopod fragments solitary coral *Catenipora* sp. *Harpidium*? sp. *Stenopareia* sp. Age: Silurian, Late Llandovery	53192
Vunta Formation, 165–174 m (542–574 ft.) below top	echinoderm and microfossil debris solitary, favositid and halysitid corals *Cystihalysites* sp. *Favosites* sp. *Halysites* sp. Age: Silurian, Llandovery	53191

Field no. and stratigraphy	Locality, fauna and age	GSC loc. no.
182 m (599 ft.) below top	*Halysites* sp. Age: Silurian, Llandovery	53189
188-192 m (618-633 ft.) below top	halysitid coral Age: Silurian, Llandovery	53188
266-229 m (743-754 ft.) below top	echinoderm fragments, solitary coral stromatoporoid, large gastropod *Catenipora* sp. *Favosites* sp. Age: Silurian, Llandovery	53187
Vunta Formation, 265 m (807 ft.) below top	echinoderm, trilobite, ostracode fragments solitary coral *Cystihalysites* sp. *Favosites* sp. *Paleofavosites* sp. Age: Silurian, Llandovery	C-124632
Vunta Formation, 381 m (1161 ft.) below top	echinoderm and gastropod fragments indeterminate large brachiopod ?*Raphistoma* sp. Age: Middle Ordovician to Silurian	C-124630
Vunta Formation, 471-473 m (1550-1556 ft.) below top, 394-396 m (1297-1303 ft.) above base	*Heterochilina*? *bursa* Copeland *Illaenus* sp. *Uromystrum* sp. Age: early Middle Ordovician, Whiterock to Chazy	53185-6
Vunta Formation, 480-482 m (1578-1585 ft.) below top	indeterminate gastropod	53184
Vunta Formation, 658 m (2166 ft.) below top	indeterminate gastropod	53183
Vunta Formation, 844 m (2778 ft.) below top, 23 m (75 ft.) above base	fossil debris Age (53183-4, 54665): indeterminate	54665

C.D.R. Tenlen Lake A-73 well

(Fig. 1, loc. 99; MacKenzie, 1974; Pugh, 1983, Appendix II) 67°52′07″N, 130°43′21″W

3072 ft. Top of Peel Formation

3214-3222 ft.	*Oulodus*? sp. *Ozarkodina* sp. *Panderodus* sp. poorly preserved brachiopods (cf. *Atrypoidea*) Age: possibly Late Silurian (CAI 2)	C-111453

Field no. and stratigraphy	Locality, fauna and age	GSC loc. no.
3268 ft., 0″–2″	*Favosites* sp. Age: Silurian to Devonian	C–111454
3281–3317 ft.	*Oulodus* sp. *Ozarkodina dourensis* Uyeno *Panderodus* sp. Age: Late Silurian, Ludlow, *siluricus* Zone (CAI 2; Uyeno)	C–111455
3517 ft.	fish fragments, Family Cyathaspididae Age: probably Late Silurian, Ludlow to Pridoli (Thorsteinsson)	C–28116
3777 ft., 2″–5″	indeterminate brachiopod	C–111456
3784–3792 ft.	*Panderodus* sp. (CAI 2, Uyeno)	
	3828 ft. Top of Mount Kindle Formation	
3878 ft., 6″–7″	*Favosites*? sp.	C–111458
3968 ft., 0″–2″	*Catenipora*? sp.	C–111460
4187–4194 ft.	*Panderodus* sp. (CAI 2–2.5, Uyeno)	C–111461
4316–4317 ft.	*Favistina* sp. *Palaeophyllum* sp. streptelasmid coral	C–28262
4323 ft.	*Catenipora* sp. *Palaeophyllum*? sp.	C–28261
4325–4326 ft.	*Bighornia*? sp. *Catenipora* sp. *Lobocorallium* sp. *Palaeophyllum* sp. *Paleofavosites* sp.	C–111462
4331 ft., 0″–4″	*Calapoecia* sp. *Catenipora* sp.	C–111463
4337 ft., 0″–2″	*Catenipora*? sp.	C–111464
4347 ft.	streptelasmid coral	C–28264
4361 ft., 0″–4″	*Palaeophyllum* sp.	C–111465
4402 ft., 0″–4″	echinoderm fragments *Calapoecia* sp. *Palaeophyllum* sp.	C–111466

Field no. and stratigraphy	Locality, fauna and age	GSC loc. no.
4414 ft., 0″-1″	streptelasmid coral Age: (4316-4414 ft.): Late Ordovician, Ashgill or Late Caradoc	C-111467

4539 ft. Top (revised) of Franklin Mountain Formation

James River Section

(Fig. 1, loc. 20) 66°53′N, 136°11′W

Field no. and stratigraphy	Locality, fauna and age	GSC loc. no.
Road River Group, 710 m above lower unit	*Monograptus* cf. *M. thomasi* Jaeger Age: Early Devonian, Pragian, probably *thomasi* Zone	C-104217
Road River Group, felsenmeer at 572 m above lower unit	*Bohemograptus bohemicus* (Barrande) Age: Late Silurian, Ludlow, *nilssoni* Zone or *leintwardinensis primus* Zone	C-104216
Road River Group, 411-421 m above lower unit	*Cyrtograptus* cf. *C. lapworthi* Tullberg *C. sakmaricus* Koren *Monograptus* spp. *M.* ex gr. *M. priodon* (Bronn) *M.* ex gr. *M. spiralis* (Geinitz) *Retiolites*? sp. Age: Early Silurian, latest Llandovery, *sakmaricus-laqueus* Zone	C-104215
Road River Group, 351-451 m above lower unit	sponge spicules indeterminate eoligonodiniform and trichonodelliform conodont elements Age: presumably post-Llandovery (CAI 5; G.S. Nowlan)	C-104166
Road River Group, 323 m above lower unit	*Monograptus* spp. *M. exiguus primulus* Boucek and Pribyl *M. turriculatus* (Barrande) *Pseudoplegmatograptus obesus obesus* (Lapworth) Age: Early Silurian, Late Llandovery, *turriculatus* Zone	C-104214
Road River Group, 251-351 m above lower unit	*Aulacognathus bullatus* (Nicoll and Rexroad) *Dapsilodus obliquicostatus* (Branson and Mehl) *Decoriconus* sp. *Distomodus* cf. *D. kentuckyensis* Branson and Branson of Cooper (1975) *Distomodus staurognathoides* (Walliser) *Oulodus*? *fluegeli* (Walliser) *O.*? *kentuckyensis* (Branson and Branson) *Ozarkodina polinclinata* (Nicoll and Rexroad) *Panderodus gracilis* (Branson and Mehl) *Walliserodus curvatus* (Branson and Branson) Age: Early Silurian, Llandovery (CAI 5; G.S. Nowlan)	C-104165

Field no. and stratigraphy	Locality, fauna and age	GSC loc. no.
Road River Group, 293 m above lower unit	*Monograptus* spp. *M.* cf. *M. planus* (Barrande) *M.* cf. *M. turriculatus* (Barrande) *Petalograptus*? sp. *Rastrites* sp. Age: Early Silurian, Late Llandovery, *turriculatus* Zone	C–104213
Road River Group, 256 m above lower unit	*Climacograptus* ex gr. *C. bicornis* Hall *Dicellograptus* sp. *Orthograptus*? sp. Age: late Middle or Late Ordovician, *gracilis* Zone to *complanatus ornatus* Zone	C–104212
Road River Group, 182 m above lower unit	*Dicellograptus* sp. *Glyptograptus* sp. Age: late Middle or Late Ordovician, *gracilis* Zone to *complanatus ornatus* Zone	C–104211
Road River Group, 51–151 m above lower unit	*Protopanderodus* sp. ramiform element indet. Age: Ordovician (G.S. Nowlan)	C–104163
Road River Group, 92 m above lower unit	*Amplexograptus*? sp. *Didymograptus* sp. *Pseudobryograptus* sp. Age: early Middle Ordovician, probably *tentaculatus* Zone	C–104210
Road River Group, 59 m above lower unit	*Caryocaris* sp. *Didymograptus* spp. *D.* sp. (extensiform) *Glossograptus* sp. *Glyptograptus*? sp. *Isograptus* sp. *Loganograptus* sp. *Tetragraptus* sp. *T.* cf. *T. pendens* Elles *T.* cf. *T. quadribrachiatus* (Hall) *Tylograptus*? sp. Age: early Middle Ordovician, *tentaculatus* Zone	C–104209
Road River Group, 14 m above lower unit	*Dendrograptus* sp. *Didymograptus* sp. (extensiform) *Glossograptus* sp. *Glyptograptus* sp. *Goniograptus*? sp. *Isograptus caduceus* (Salter) *Loganograptus*? sp. *Tetragraptus* sp. *T.* cf. *T. quadribrachiatus* (Hall) *Tristichiograptus ensiformis* (Hall) Age: early Middle Ordovician, *tentaculatus* Zone	C–104208

Field no. and stratigraphy	Locality, fauna and age	GSC loc. no.
Road River Group, basal 51 m of upper unit, top 49 m of lower unit	drepanodiform element ?*Oistodus* cf. *O. multicorrugatus* Harris *Periodon* sp. *Protopanderodus* sp. *Scolopodus emarginatus* Barnes and Tuke Age: Early Ordovician, Arenig, late Canadian Faunas D and E of Ethington and Clark, 1971 (CAI 5; G.S. Nowlan)	C–104162
Road River Group, top 5 m of lower unit	*Didymograptus* sp. (extensiform) *Phyllograptus* sp. *Tetragraptus*? sp. Age: Early Ordovician, *fruiticosus* Zone to *victoriae* Zone	C–104207
Road River Group, 3 m below top of lower unit	*Clonograptus*? sp. *Didymograptus extensus* (Hall) *Tetragraptus fruticosus* (Hall), 3 and 4 branched forms *T.* cf. *T. quadribrachiatus* (Hall) Age: Early Ordovician, *fruticosus* Zone (upper part)	C–104206
Road River Group, 6 m below top of lower unit	graptolite fragments *Clonograptus* sp. *Dichograptus* cf. *D. octobrachiatus* (Hall) *Dictyonema* sp. *Didymograptus extensus* (Hall) *Tetragraptus* cf. *T quadribrachiatus* (Hall) Age: Early Ordovician, *fruticosus* Zone to lower part of *victoriae* Zone	C–104205

Rock River (main tributary) Section

(Fig. 1, loc. 22) 66°43′N, 136°08′W

Field no. and stratigraphy	Locality, fauna and age	GSC loc. no.
Road River Group, top 175 m of lower unit	inarticulate brachiopod *Cordylodus* sp. *Oneotodus simplex* (Furnish) *Paltodus bassleri* Furnish s.f. *Teridontus* cf. *T nakamurai* (Nogami) Age: Early Ordovician, early Canadian, probably Fauna C (CAI 5; G.S. Nowlan)	C–104187
Road River Group, 175-275 m below upper unit	inarticulate brachiopod *Cordylodus proavus* Müller *Eoconodontus notchpeakensis* (Miller) *Proconodontus muelleri muelleri* Miller *Teridontus nakamurai* (Nogami) Age: Late Cambrian to earliest Ordovician (CAI 5; G.S. Nowlan)	C–104186

Field no. and stratigraphy	Locality, fauna and age	GSC loc. no.
Road River Group, 280 m below upper unit	*Dendrograptus* sp. *Dictyonema* sp. Age: Late Cambrian to earliest Ordovician	C–104218
Road River Group, 275–375 m below upper unit	*Eoconodontus notchpeakensis* (Miller) *Proconodontus*? sp. *Prooneotodus tenuis* (Müller) *P. tenuis* fused cluster indeterminate multicostate simple cone Age: Late Cambrian to earliest Ordovician (G.S. Nowlan)	C–104185
Road River Group, 375–475 m below upper unit	inarticulate brachiopod tubercular plates of unknown affinity *Eoconodontus*? sp. *Proconodontus muelleri muelleri* Miller *Prooneotodus gallatini* (Müller) *Prooneotodus tenuis* (Müller) Age: Late Cambrian to possibly early Ordovician (G.S. Nowlan)	C–104184
Road River Group, 475–575 m below upper unit	inarticulate brachiopod *Prooneotodus tenuis* (Müller) Age: probably Late Cambrian (G.S. Nowlan)	C–104183
Road River Group, 575–675 m below upper unit	*Furnishina*? sp. *Prooneotodus tenuis* (Müller) Age: probably Late Cambrian (G.S. Nowlan)	C–104182
Road River Group, 675–775 m below upper unit	inarticulate brachiopod *Prooneotodus tenuis* (Müller) Age: probably Late Cambrian (G.S. Nowlan)	C–104181
Road River Group, 875–975 m below upper unit	inarticulate brachiopod sponge spicules phosphatic rods of unknown affinity *Furnishina primitiva* Müller *Prooneotodus tenuis* (Müller) Age: Late Cambrian (G.S. Nowlan)	C–104179
Road River Group, 975–1075 m below upper unit	sponge spicules *Prooneotodus tenuis* (Müller) Age: Late Cambrian (G.S. Nowlan)	C–104178
Road River Group, 1075–1175 m below upper unit	inarticulate brachiopod annulated phosphatic tubes (hyolithellids?) ?*Prooneotodus gallatinia* (Müller) *Prooneotodus tenuis* (Müller) Age: Late Cambrian (G.S. Nowlan)	C–104177

Field no. and stratigraphy	Locality, fauna and age	GSC loc. no.
Road River Group, 1275–1375 m below upper unit	inarticulate brachiopod phosphatic rods of unknown affinity *Pseudopanderodus*? aff. *P.*? *fisheri* Landing Age: probably Late Cambrian (G.S. Nowlan)	C–104175
Road River Group, 1445 m below upper unit	*Dendrograptus* sp.	C–104220
Road River Group, 1463–1465 m below upper unit	*Dendrograptus* sp. Age: Late Cambrian (C–104220 and C–104219)	C–104219
Road River Group, 1475–1575 m below upper unit	inarticulate brachiopod *Prooneotodus tenuis* (Müller) Age: probably Middle or Late Cambrian (G.S. Nowlan)	C–104173
Road River Group, 1675–1775 m below upper unit	inarticulate brachiopod *Prooneotodus*? sp. Age: not diagnostic (G.S. Nowlan)	C–104171
	Dempster Highway, 1 km W., near pass	
	(Fig. 1, near loc. 20) 66°57′N, 136°16′W	
Road River Group, 8 m above C–104237	*Monograptus yukonensis* Jackson and Lenz Age: Early Devonian, Pragian, *yukonensis* Zone	C–104238
Road River Group, 8 m below C–104238	*Monograptus* cf. *M. telleri* Lenz and Jackson Age: Early Devonian, Pragian, probably *thomasi* Zone	C–104237
	Mt. Cronin	
	(Fig. 1, near loc. 22) N. of 66°45′N, 136°12′W	
Road River Group, felsenmeer at 100–105 m below top of lower unit	*Caryocaris* sp. *Clonograptus*? sp. *Dendrograptus* sp. *Didymograptus* cf. *D. extensus* (Hall) *Tetragraptus* sp. *T. approximatus* Nicholson Age: Early Ordovician, *approximatus* Zone and/or *fruticosus* Zone	C–104239
	James River	
	(Fig. 1, near loc. 20) first quarry about 3 km N of 66°56′N, 136°15′W	
Road River Group	*Monograptus yukonensis* Jackson and Lenz Age: Early Devonian, Pragian, *yukonensis* Zone	C–104240

Field no. and stratigraphy	Locality, fauna and age	GSC loc. no.
	Tetlit Creek Section	
	(Fig. 1, loc. 21; Norford, 1964, p. 97–108, 134–135) 66°43′N, 135°49–53′W	
Road River Group, upper member, 757 m above base, 43 m below top	*Monograptus yukonensis* Jackson and Lenz Age: Early Devonian, Pragian, *yukonensis* Zone	C–104226
Road River Group, upper member, 730 above base, 70 m below top	*Monograptus* cf. *M. thomasi* Jaeger Age: Early Devonian, Pragian, probably *thomasi* Zone	C–104225
Road River Group, upper member, 524–624 m above base, 176–276 m below top	*Icriodus* sp. *Ozarkodina paucidentata* Murphy and Matti *O. remscheidensis remscheidensis* (Ziegler) Age: Early Devonian, early Lochkovian, *hesperius* Zone to *eurekaensis* Zone (T.T. Uyeno)	C–104191
Road River Group, upper member, 424–524 m above base, 276–376 m below top	*Icriodus* cf. *I woschmidti* Ziegler *Ozarkodina excavata* (Branson and Mehl) *Panderodus* sp. *Pseudooneotodus* sp. Age: probably latest Silurian (late Pridoli) to Early Devonian (Lochkovian) (T.T. Uyeno)	C–104190
	Road River	
	(Fig. 1, loc. 44) just to south of 66°35′N, 135°32′W	
Road River Group, debris flow, 100–200 m above C–104242	echinoderm columnals (double axis type) atrypid brachiopod solitary and alveolitid corals *Taimyrophyllum* sp. stromatoporoid Age: Early Devonian to early Middle Devonian; probably Zlichovian (A.E.H. Pedder)	C–104241
Road River Group, 100–200 m below C–104241	*Monograptus yukonensis* Jackson and Lenz Age: Early Devonian, Pragian, *yukonensis* Zone	C–104242
	Hillard Peak	
	(Fig. 1, loc. 95) 64°57′N, 141°00′W	
Road River Group, 10 m above Hillard Formation	*Climacograptus*? sp. *Dicellograptus* sp. *Glyptograptus*? sp. *Reteograptus*? sp. Age: late Middle or Late Ordovician, Caradoc or Ashgill	C–101555

CHAPTER 7

DEVONIAN

A.W. Norris

Norris, A.W., 1996. Devonian. In The Geology, Mineral and Hydrocarbon potential of Northern Yukon Territory and Northwestern District of Mackenzie, Geological Survey of Canada, Bulletin 422, p. 163–200.

Abstract

During Early and Middle Devonian time, carbonate successions were deposited on the Mackenzie Platform in the east, on the Yukon Stable Block in the west, and on two small isolated platforms: the White Mountains Platform in the north and the Royal Mountain Platform in the south. During the same time interval, successions consisting largely of shale were deposited in the central Richardson Trough and in the peripheral Blackstone, Selwyn, Hazen and Rapid troughs.

The Lower and Middle Devonian successions on the Mackenzie Platform consist of the Unnamed carbonate unit, along with the Cranswick, Hume, and Hare Indian formations. Slope deposits comprising a tongue of the Road River Formation and the Mount Baird Formation are transitional between the Mackenzie Platform and Richardson Trough. On the Yukon Stable Block in the west, the carbonate succession consists of the Kutchin and Ogilvie formations and an Unnamed shale unit. A succession showing a fluctuation between basinal shale and carbonate platform deposits comprises the Road River and Michelle formations in the Blackstone Trough, and the Ogilvie Formation and the Unnamed shale unit on the Yukon Stable Block. During the same interval, deeper water sediments of the Road River Formation were deposited in the troughs.

The uppermost Middle and Upper Devonian successions are completely different from older Devonian sedimentary rocks, comprising the Canol, Imperial and Tuttle formations. The upper Middle Devonian Canol Formation is a widespread dark euxinic shale which is locally separated from underlying rock units by an unconformity. The succeeding Upper Devonian Imperial and Tuttle formations consist of fine to coarse grained clastic rocks of turbidite origin derived from an uplifted area in the north. The Tuttle Formation capping the succession is dated by spores as latest Late Devonian and Early Carboniferous.

Résumé

Durant le Dévonien précoce et moyen, des successions carbonatées se sont déposées sur la plate-forme de Mackenzie dans l'est, sur le bloc stable du Yukon dans l'ouest et sur deux petites plate-formes isolées : la plate-forme de White Mountains dans le nord et la plate-forme de Royal Mountain dans le sud. Durant le même intervalle, des successions surtout composées de shale se sont déposées dans le centre de la cuvette de Richardson et dans les cuvettes périphériques de Blackstone, de Selwyn, de Hazen et de Rapid.

Les successions du Dévonien inférieur et moyen sur la plate-forme de Mackenzie se composent d'une unité carbonatée non désignée ainsi que des formations de Cranswick, de Hume et de Hare Indian. Les dépôts de talus renfermant une langue de la Formation de Road River et la Formation de Mount Baird forment une transition entre la plate-forme de Mackenzie et la cuvette de Richardson. Sur le bloc stable du Yukon dans l'ouest, la succession carbonatée est composée des formations de Kutchin et d'Ogilvie et d'une unité de shale non désignée. Une succession montrant une fluctuation entre les shales de bassin et les roches carbonatées de plate-forme comprend les formations de Road River et de Michelle dans la cuvette de Blackstone, ainsi que la Formation d'Ogilvie et l'unité de shale non désignée sur le bloc stable du Yukon. Durant le même intervalle, des sédiments d'eau plus profonde de la Formation de Road River se sont déposés dans les cuvettes.

Les successions de la partie sommitale du Dévonien moyen et du Dévonien supérieur sont complètement différentes des roches sédimentaires dévoniennes plus anciennes, comprenant les formations de Canol, d'Imperial et de Tuttle. La partie supérieure de la Formation de Canol du Dévonien moyen est un shale euxinique foncé répandu qui est localement séparé des unités lithologiques sous-jacentes par une discordance. Les formations d'Imperial et de Tuttle du Dévonien supérieur qui lui succèdent renferment des roches clastiques à grain fin à grossier d'origine turbiditique dérivées d'une zone soulevée dans le nord. La Formation de Tuttle surmontant la succession a été datée à partir de spores à la toute fin du Dévonien tardif et au Carbonifère précoce.

INTRODUCTION

This chapter is a review and update of the detailed account by A.W. Norris (1985) which covered the Geology of the Devonian outcrop belts of northern Yukon Territory and northwestern District of Mackenzie. For brevity, this review is restricted to a discussion of the Devonian stratigraphy, biostratigraphy, paleogeography, and paleophysiographic subdivisions. The area lies between latitude 65°N and the Arctic Coast, and between longitudes 132°W and 141°W (Yukon/Alaska border), covering about 207 200 km^2 (Fig. 7.1). The A.W. Norris (1985) report was based mainly on 49 outcrop sections measured in 1962, 1970 and 1982, and incorporated biostratigraphical and other data published since the earlier reports of A.W. Norris (1968a, b). This review is intended to supplement the information presented on sixteen geological maps by D.K. Norris covering the Operation Porcupine area at a scale of 1:250 000.

STRATIGRAPHY

Main Devonian outcrop belts

Devonian sedimentary rocks are widespread and well exposed in the study area (Figs. 7.1, 7.2), especially in the folded mountain belts in the southern half of the area. The Lower and Middle Devonian Series are represented by both carbonate platform and basinal shale facies that outcrop mainly in the Mackenzie, Richardson and Ogilvie mountains. Smaller scattered outcrop areas are also present in the Keele Range, Porcupine Plain, and in the cores of the White and Campbell uplifts. The Upper Devonian Series consists largely of recessive weathering clastic rocks that outcrop on the plateaus and lowlands flanking the Mackenzie, Wernecke, Ogilvie and Richardson mountains. These rocks also underlie a large drift-covered area immediately south and east of the upper part of Mackenzie Delta.

Lower and Middle Devonian carbonate platform successions occur in the east on the Mackenzie Platform, in the northeast on Cambell Uplift, and in the west on the Yukon Stable Block. Equivalent successions, consisting mainly of shale or shale and minor carbonate, were deposited in the centrally located Richardson Trough, and in the peripheral Blackstone, Selwyn, Hazen and Rapid troughs.

The upper Middle and Upper Devonian and Lower Carboniferous successions, starting with dark shale of the Canol Formation followed by clastic rocks of the Imperial and Tuttle formations, were deposited under a completely different sedimentary regime, with the clastic rocks reflecting the onset of uplift and orogeny in the north. Igneous intrusions, radiometrically dated as Late Devonian and older, occur in the northwestern part of the area and are related to the Ellesmerian Orogeny.

Kutchin Formation

The Kutchin Formation, named after the indigenous Kutchin Indians (Swanton, 1952), was introduced by A.W. Norris (1985) to apply to the succession of dolomite and dolomitic limestone that overlies a variety of carbonate rocks of Ordovician and Silurian ages, and underlies the Ogilvie Formation (Fig. 7.3). The type section is at locality 30 (Fig. 7.1; A.W. Norris, 1985, fig. 8) in southeastern White Uplift, where A.W. Norris (1968b, p. 232–235, fig. 5) had formerly included it in the Gossage Formation, a name now considered obsolete by Pugh (1983).

The formation is developed on the White Mountains Platform and throughout a large part of the Yukon Stable Block, where only the upper part of the formation is generally exposed. It is thin or missing in the vicinity of Mount Burgess on the eastern flank of the Dave Lord High. The only section where it is completely exposed on the Yukon Stable Block is at

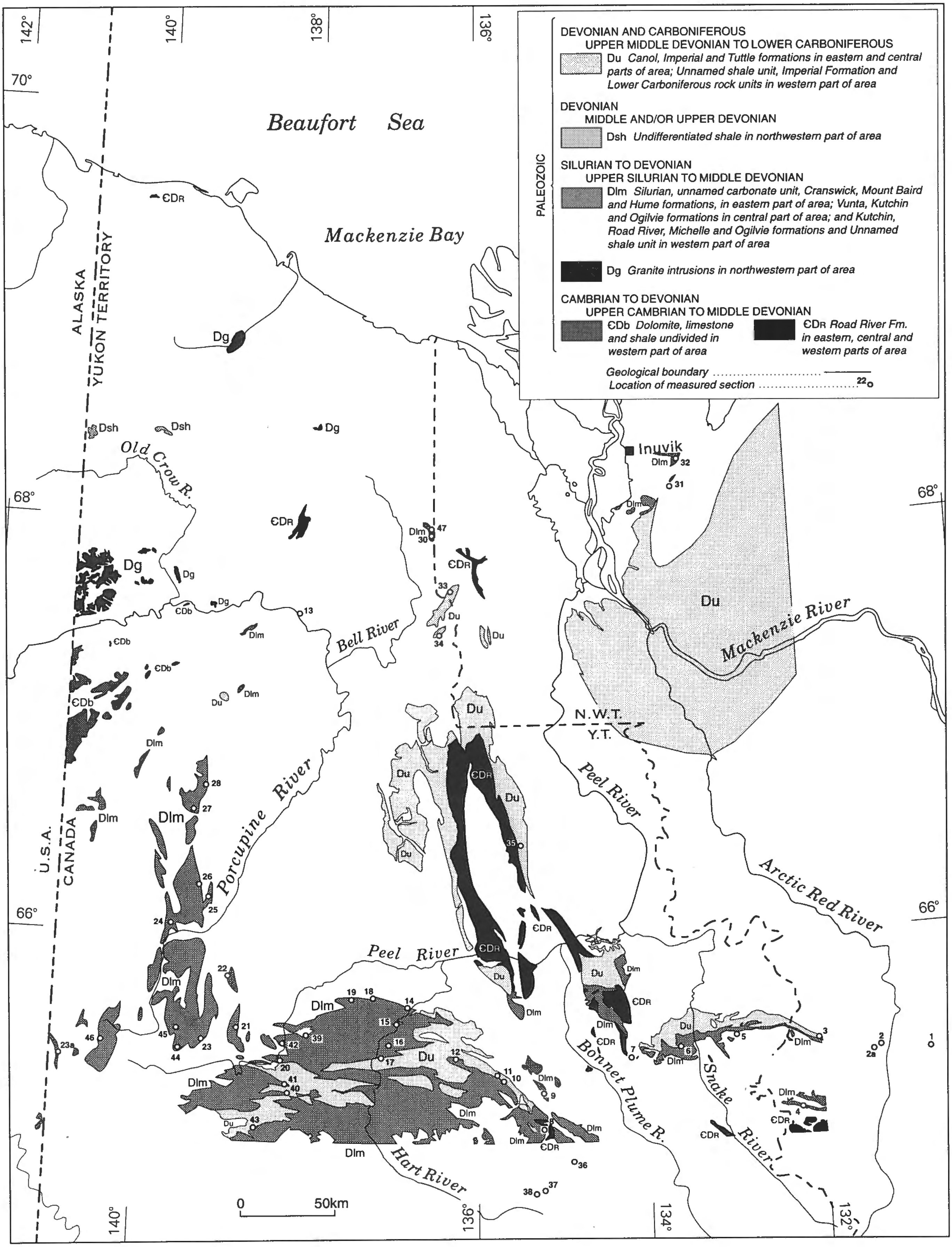

Figure 7.1. Devonian outcrop belts and locations of measured sections (A.W. Norris, 1985) in the Operation Porcupine area.

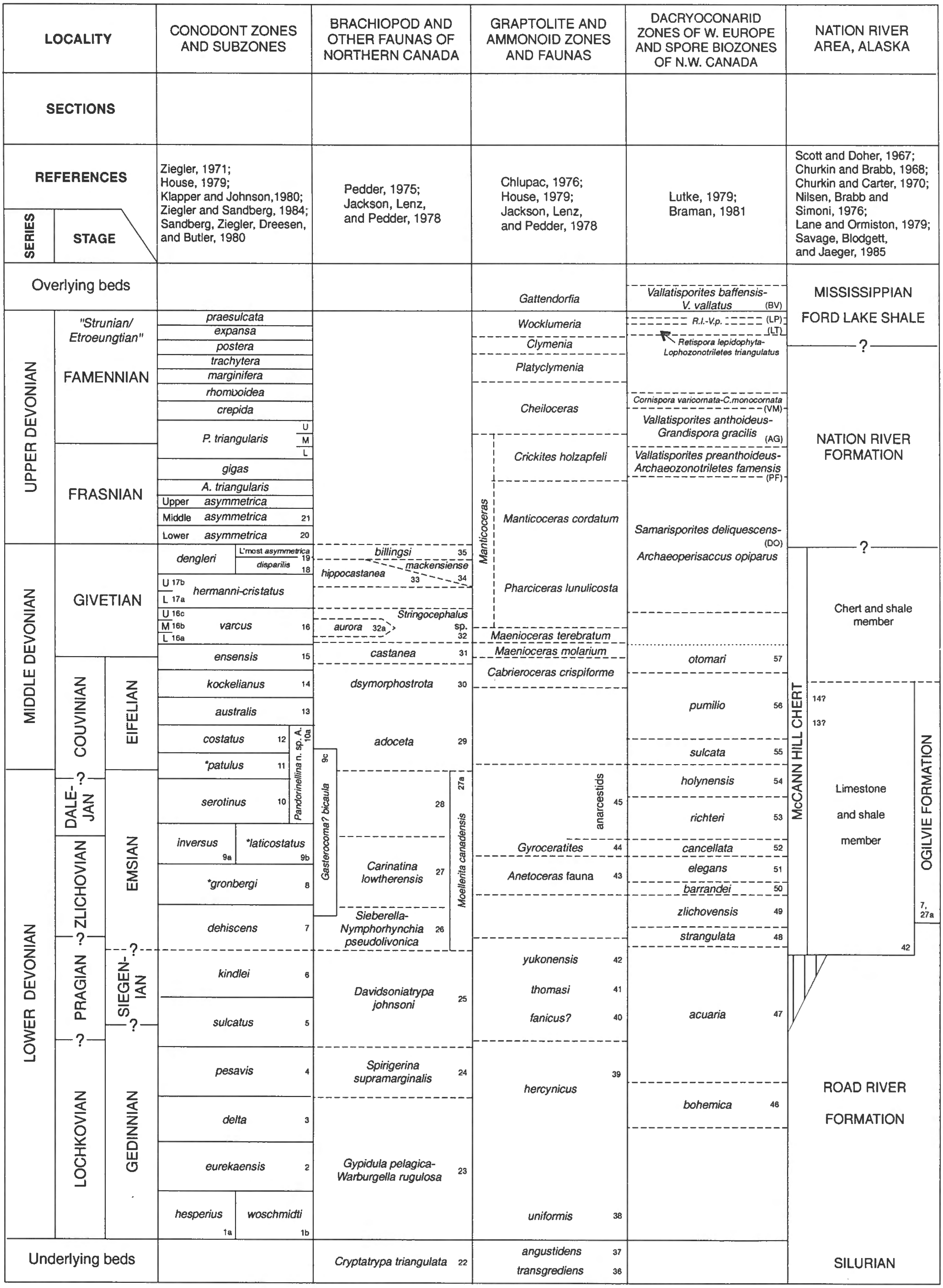

Figure 7.2. *Formational nomenclature, main faunas and floras, and correlations (A.W. Norris, 1985).*

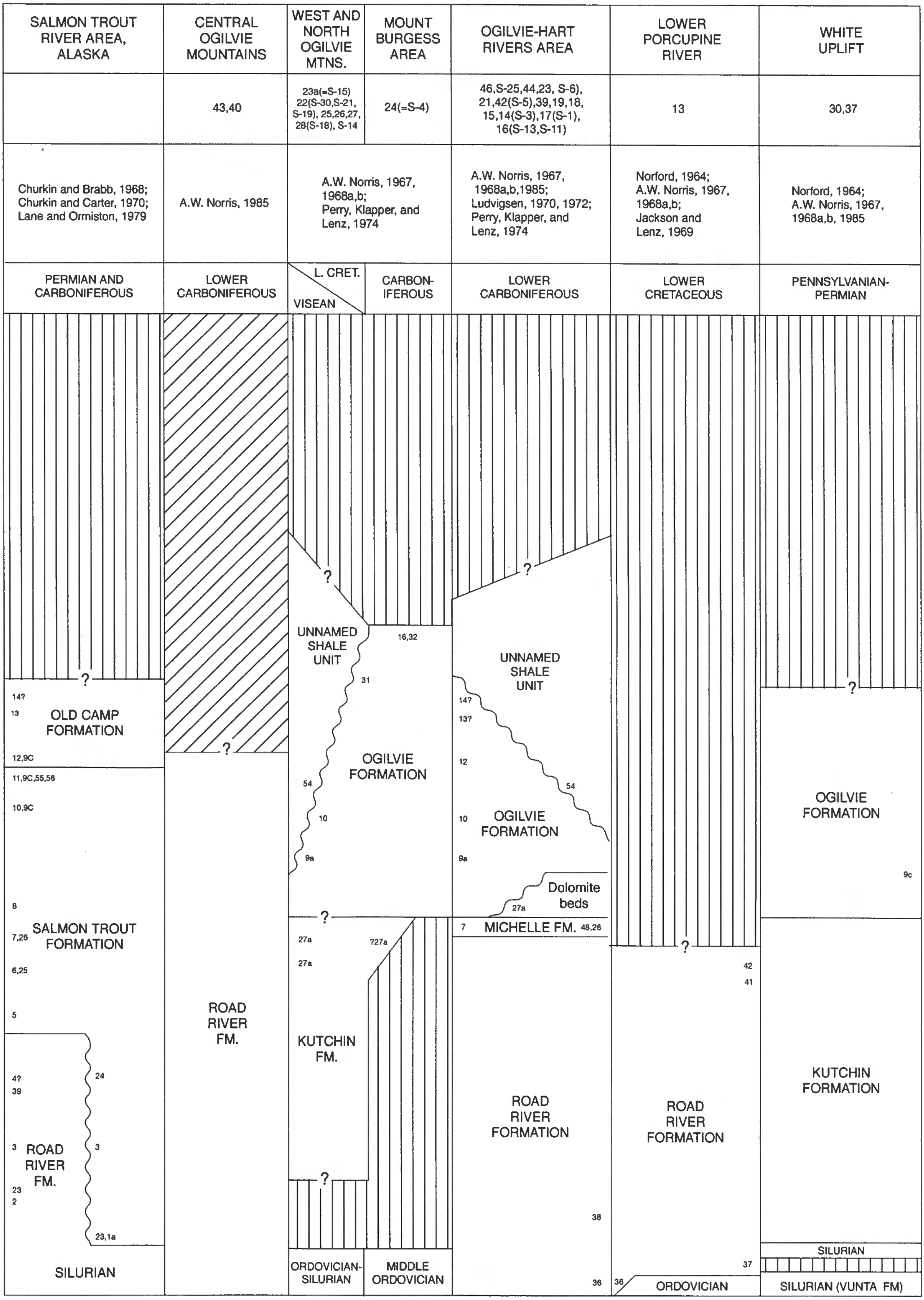

Figure 7.2. *(cont'd).*

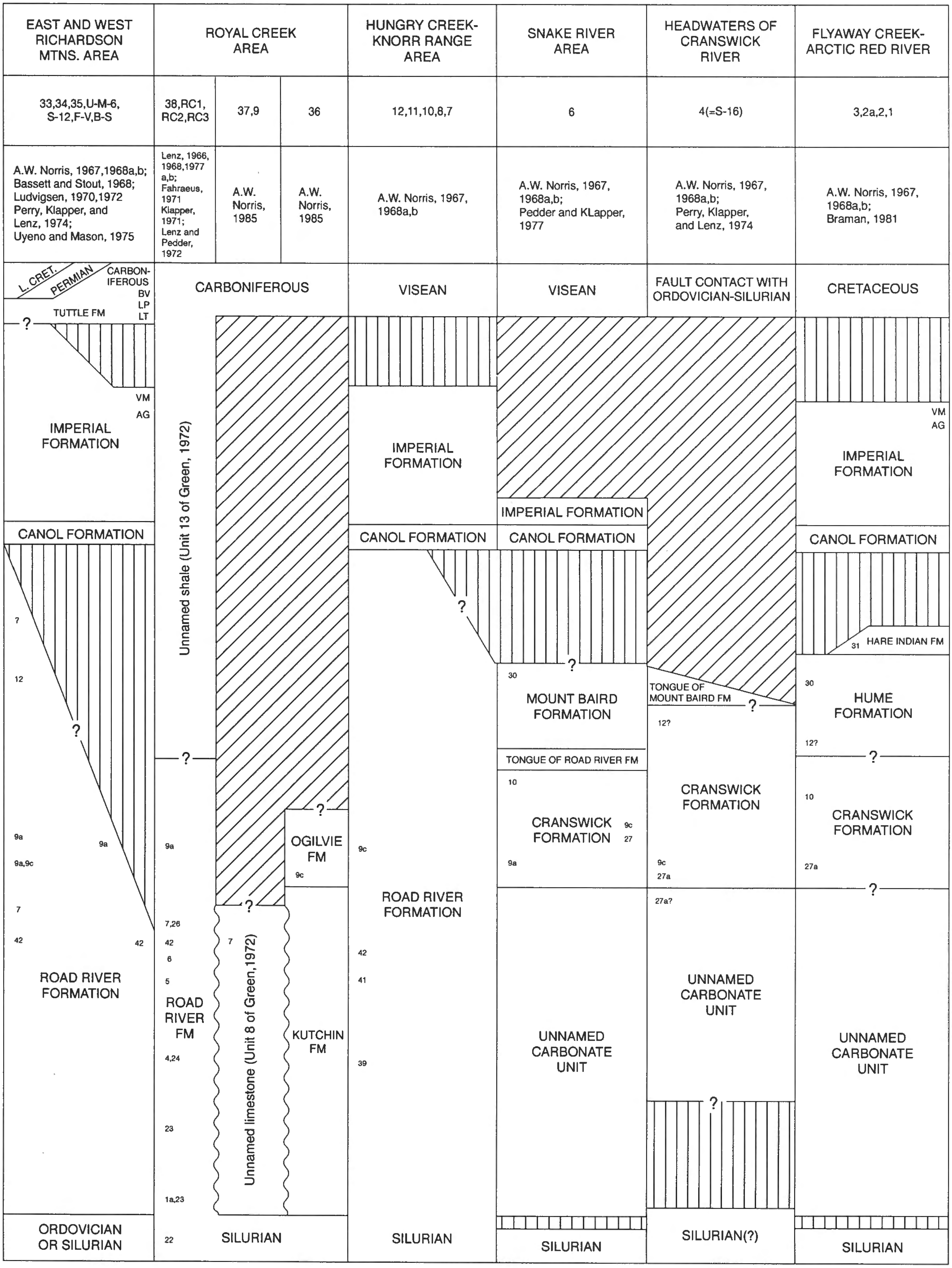

***Figure 7.2.** (cont'd).*

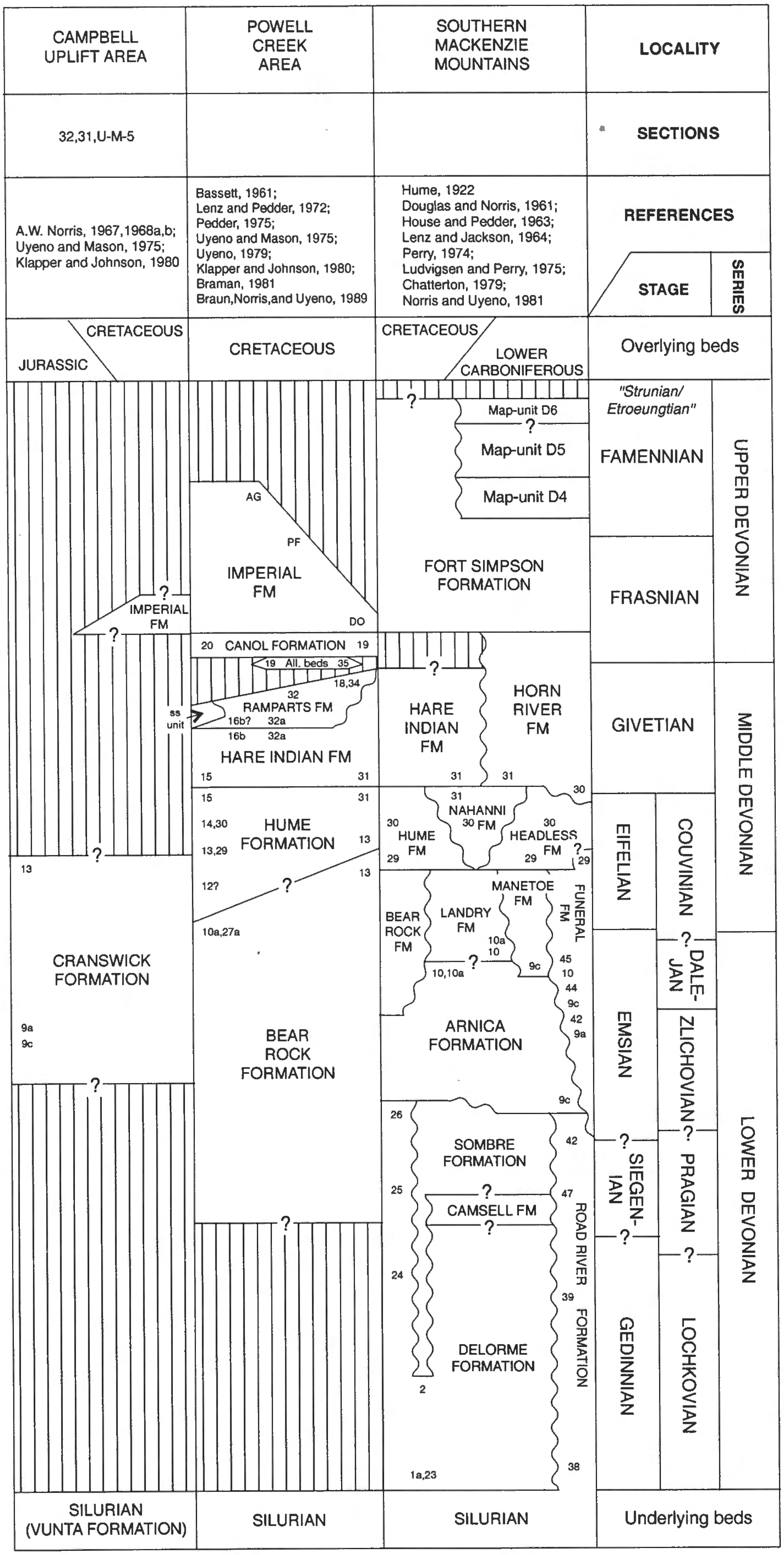

Figure 7.2. (cont'd).

Figure 7.3. Castellated weathering, thick bedded to massive limestone of the Ogilvie Formation capping a mountain, underlain by darker rubbly weathering beds of limestone and dolomite of the Kutchin Formation. View northwest at Section 28 at approximately 66°42.9′N, 139°15′W, in the northern Ogilvie Mountains. GSC photo 1991-080-6.

Mount Burgess (loc. 24; A.W. Norris, 1985, fig. 7) where it is unusually thin (107 m thick), and lithologically atypical.

The Kutchin Formation generally consists of colour banded, light to dark grey, slightly recessive, thin to thick bedded, fine grained to micritic dolomite, dolomitic limestone, and limestone. Some of the beds are slightly silty and argillaceous, and there are a few occurrences of finely brecciated dolomite. Pelletoidal limestone occurs in the upper part of the formation in some sections in northern Ogilvie Mountains. On Mount Burgess (Section 24) the formation consists of a basal unit of chert-pebble conglomerate in a matrix of reddish brown silty shale, a middle unit of red, silty and sandy shale, and an upper unit of recessive, thin bedded, finely crystalline dolomite, weathering orange-brown.

The lower contact of the Kutchin Formation in the type area is unconformable with unnamed, dark, *Atrypoidea*-bearing, Upper Silurian limestone beds, which are, in turn, separated from limestone beds of the Vunta Formation by an erosional unconformity (Norford, 1964). At Section 24 on Mount Burgess, the Kutchin Formation unconformably overlies Middle Ordovician dolomite beds. North of Mount Burgess along the east flank of the Dave Lord High, all of the Kutchin Formation and the Middle Ordovician beds are missing.

The upper contact of the Kutchin Formation is with more resistant, thicker bedded and lighter coloured limestone of the Ogilvie Formation. This contact appears to be conformable and isochronous.

Lithological features of the Kutchin Formation—including fine textures, rhythmic colour banding, a few thin brecciated layers, and lack of most invertebrate fossils except for ostracodes—suggest that the formation was deposited under restricted marine, euryhaline, platform conditions.

Commonly, the only fossil found in the upper one third of the formation is the large ostracode, *Moelleritia canadensis* Copeland (1962). The range of this distinctive ostracode spans the Emsian of the upper Lower Devonian (Fig. 7.2). The Kutchin Formation is approximately equivalent to the Unnamed carbonate unit which occurs on the Mackenzie Platform east of the Richardson Trough.

Unnamed carbonate unit

For a detailed account of the modifications of terminology applied to rocks formerly included under the term Bear Rock Formation, refer to Bassett (1961), Tassonyi (1969), Pugh (1983), and A.W. Norris (1985, p. 9, 10).

Because the names Bear Rock Formation and Gossage Formation were considered obsolete by Pugh (1983), the informal name Unnamed carbonate unit was used by A.W. Norris (1985) to apply to the sequence of restricted marine carbonate rocks that unconformably overlies carbonate rocks of Silurian age, and underlies the Cranswick Formation. This definition excludes the Landry Formation as used by Pugh (1983), which is coeval with the Cranswick Formation of A.W. Norris (1968a, b, 1985). The Unnamed carbonate unit occurs on the Mackenzie Platform and passes westward into shale of the Road River Formation in the Richardson Trough.

Representative thicknesses of the Unnamed carbonate unit along the Mackenzie Mountain front in the southeastern part of the area are: 124 m at Section 6; 165 m at Section 4; and 197 m at Section 2a (Fig. 7.1). In the R.O.C. Grandview Hills No. 1 (A-37) well (67°06′12″N, 130°52′30″W) the type Gossage Formation of Tassonyi (1969) ("Bear Rock Group" of Pugh, 1983, shown on some of his illustrations) is 484 m thick.

The lithology of the Unnamed carbonate unit at Section 2a (A.W. Norris, 1985, fig. 4) consists of the following, in ascending order: recessive, orange weathering, silty and argillaceous platy dolomite; cliff-forming, grey weathering, thick bedded to massive, micritic limestone; and colour banded light to dark grey and some orange weathering, thin to medium bedded, recessive, finely crystalline dolomite, with scattered beds of intraformational dolomite breccia in the lower quarter of the unit.

At Sections 6, 4 and 2a, the lower orange-brown weathering dolomite beds of the Unnamed carbonate unit unconformably overlie light to medium grey weathering dolomite of presumed Silurian age. In the subsurface, the contact between the lower member of the Gossage Formation and the underlying Ronning Formation is marked by a pronounced break on mechanical logs (Tassonyi, 1969).

Within and near the report area, at Sections 6 (Fig. 7.4), 4 and 2a, the contact between dolomite of the Unnamed carbonate unit and overlying limestone of the Cranswick Formation corresponds to that between Tassonyi's (1969) middle dolomite member and his upper pellet limestone member of the Gossage Formation, or between Pugh's (1983) Arnica and Landry formations.

Farther east on the Mackenzie Platform, the Unnamed carbonate unit is overlain by marly, silty, in part bioclastic, limestone and shale of the Hume Formation. In the Powell Creek-Norman Wells area, the upper contact of the Bear Rock sequence with the Hume Formation is transitional and diachronous according to faunal evidence.

Figure 7.4. View southward of cliff-forming limestone of the lower part of the Cranswick Formation capping a mountain, underlain by poorly exposed dolomite beds of the Unnamed carbonate unit. Section 6 at approximately 65°26′N, 133°35′W, immediately west of Snake River and north of Mackenzie Mountain front. GSC photo 1991-080-C.

Rocks of the Unnamed carbonate unit of the report area were deposited on the outer, western part of the carbonate shelf of the Mackenzie Platform, under relatively restricted marine conditions. These conditions resulted in very few fossils being present in the unit.

The giant ostracode, *Moelleritia canadensis* Copeland (1962), and the conodont *Pandorinellina* sp. A of Uyeno and Mason (1975), are generally the only fossils found in the upper part of the Unnamed carbonate unit. The range of *Pandorinellina* sp. A, according to Chatterton (1979, p. 168), is from the conodont *serotinus* to *costatus* zones of late Emsian (late Early Devonian) to early Eifelian (early Middle Devonian) age. The range of *M. canadensis* is from the conodont *dehiscens* to *serotinus* zones of Emsian (late Early Devonian) age (Fig. 7.2).

Fish remains from orange weathering lower beds of the Unnamed carbonate unit in the Snake River area, near Section 6, have been noted by A.W. Norris (1968b, p. 22), described by Denison (1964), Dineley (1965) and Broad and Lenz (1972), and dated as Late Silurian, or possibly Early Devonian.

Conodonts of the *australis* Zone of Eifelian (early Middle Devonian) age have been recovered by Chatterton (1979, p. 175) from the upper part of the "Bear Rock Formation" at his locality 8 (64°02′N, 123°29′32″W), east of Mackenzie River. Their age indicates that the contact between the "Bear Rock Formation" and overlying Hume Formation is a diachronous facies boundary which is younger in the east and older in the west.

Road River Formation and Tongue

The name Road River Formation was introduced by Jackson and Lenz (1962, p. 32) to apply to dark coloured graptolite shale, limestone, chert, dolomite, siltstone and sandstone of Ordovician to Silurian age that outcrop in the Richardson Trough. It was later recognized in the Blackstone, Selwyn, Rapid and Hazen troughs (Fig. 7.5). The type section is on Tetlit Creek, a tributary of Road River (Norford, 1964, p. 3). Within the Richardson Trough the Road River Formation is greater than 3000 m thick, and is now known to range in age from the Late Cambrian to Middle Devonian. The name Prongs Creek Formation was introduced by A.W. Norris (1968b, p. 23) to apply to that part of the Devonian shale lying above the highest graptolites and below the Canol and Imperial formations. Used in this sense, the Prongs Creek Formation is closely similar to the McCann Hill Chert

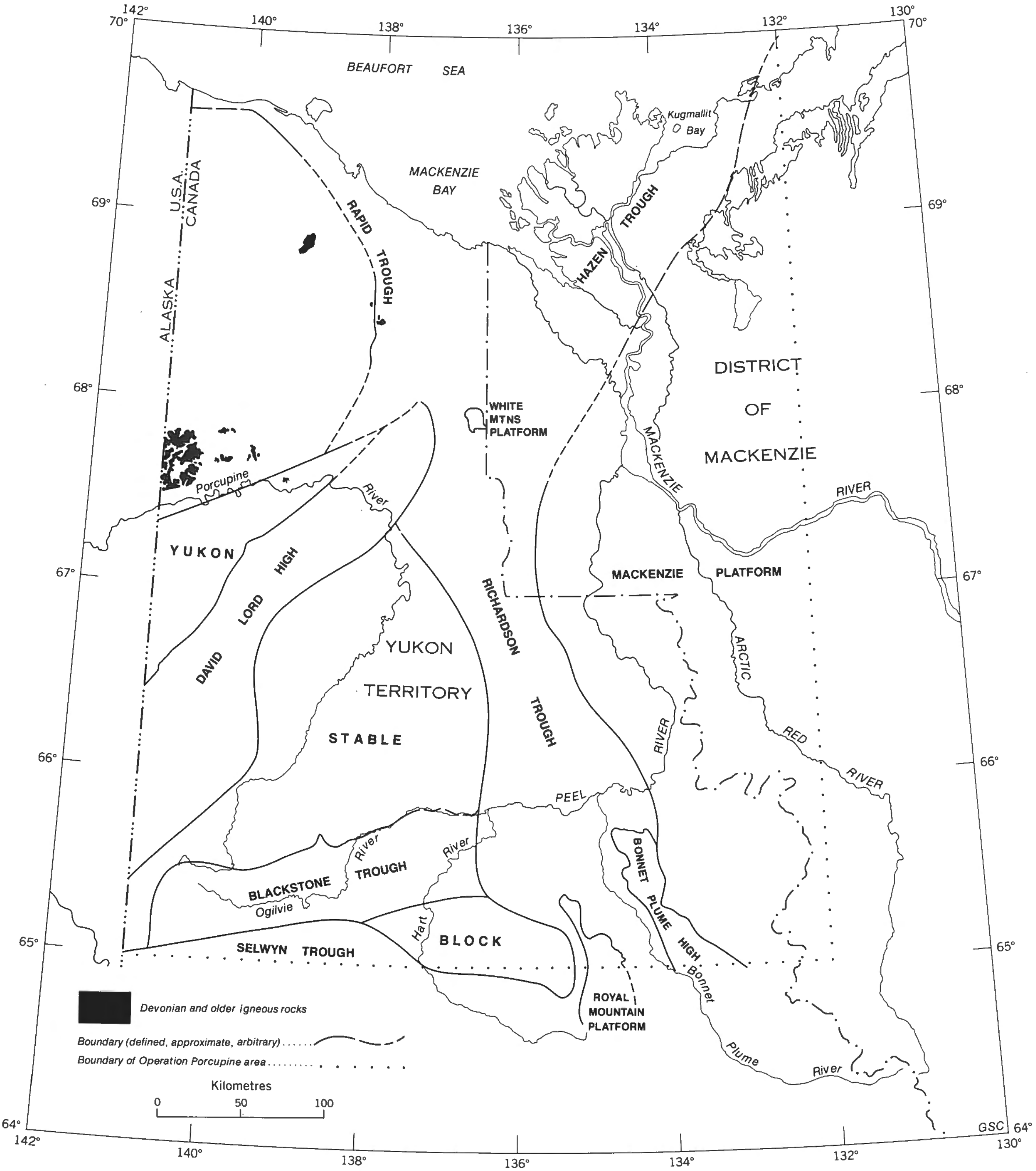

Figure 7.5. Paleophysiographic subdivisions of the report area (A.W. Norris, 1985).

of Churkin and Brabb (1965, p. 180) which typically occurs in the Nation River area of east-central Alaska. Currently, the name Road River Formation is used because of the lack of a consistent and conspicuous lithological marker for the base of the Prongs Creek Formation.

The depocentre for the Devonian part of the Road River Formation is probably at or near Section 8 on Royal Creek where a maximum thickness of 1040 m was measured (A.W. Norris, 1985, fig. 6). To the east it thins to 828 m at Section 7 in Knorr Range (Fig. 7.6) and pinches out to a 118 m thick tongue between the Cranswick and Mount Baird formations at Section 6 near Snake River (A.W. Norris, 1985, fig. 5). To the south, at the headwaters of Royal Creek, it is about 400 m thick (Lenz, 1977a, p. 40, fig. 2), and to the north, at Section 13 on Porcupine River over the north end of the Dave Lord High, it thins to 137 m (A.W. Norris, 1985, fig. 7).

The Devonian part of the Road River Formation consists of four main rock units. In ascending order these are: graptolitic shale with widely spaced dark micritic limestone beds; dark grey to black shale with widely spaced thin interbeds of limestone and argillaceous limestone, some of which are brecciated and show graded bedding; interbedded fossiliferous encrinal limestone, argillaceous limestone, and minor shale and chert; and interbedded dark grey siliceous shale and chert which is barren of fossils, except for minor scattered plant tissue. Rock units 2 to 4 of this succession were formerly classified by A.W. Norris (1968a, b) as the Prong Creek Formation.

Near the mouth of lower Peel River Canyon (65°58′N, 134°50′W) and on Solo Creek (65°51′25″N, 134°15′13″W), Perry et al. (1974, p. 1058) reported very large exotic blocks of encrinal limestone and limestone breccia within the uppermost part of the Road River Formation. Also, Macqueen (1974, p. 325, 326) and Lenz (1972, p. 328), described about 20 carbonate banks or biostromes on the east flank of Knorr Range, near Section 7 of this report, which occur in the upper third of a 610 m sequence of shale of the Road River Formation. These exotic blocks and carbonate build-ups appear to occur within Unit 3 of the Devonian part of the Road River Formation.

Figure 7.6. Road River Formation exposed on a south-facing mountain slope and in the creek valley. Section 7 at approximately 65°23′N, 134°11′W, in the Knorr Range. GSC photo 112934–I.

The lower boundary of the Devonian part of the Road River Formation is not marked by lithological changes, consequently fossils are needed for placing it within the sequence. The base of the Devonian is marked by the presence of the condont *Icriodus woschmidti* Ziegler, the graptolite *Monograptus uniformis uniformis* Pribyl, and the brachiopods *Gypidula pelagica* (Barrande), *Ancillotooechia infelix* (Barrande) and *Spiriferina marginaliformis* Alekseeva.

The upper boundary of the Road River Formation is highly variable from place to place. In the Hart–Blackstone–Ogilvie rivers area it is marked by the base of the Michelle Formation (Fig. 7.7); on the east and west flanks of the Richardson Anticlinorium, by the base of the Canol Formation; at Section 13 on lower Porcupine River, by Albian conglomeratic beds (D.K. Norris, 1974, p. 30; Jeletzky, 1972); in the Nation River area of east-central Alaska, by the base of the Limestone and shale member of the McCann Hill Chert (Churkin and Brabb, 1968); in the Salmontrout River area of east-central Alaska, by the base of the Salmontrout Limestone (Lane and

Figure 7.7. Dark graptolitic shale of the Road River Formation present along the lower one third of the slope, overlain by the Michelle Formation along the middle part of the slope. Castellated weathering beds of the Ogilvie Formation cap the mountain. View west-northwest at Section 14 at approximately 65°38.2′N, 135°45.4′W, in the northern Ogilvie Mountains. GSC photo 1991–080–H.

Ormiston, 1979); and on the north flank of Romanzof Uplift, lower Firth River area, by the Upper Triassic Shublik Formation (D.K. Norris, 1986).

The predominantly argillaceous rocks of the Road River Formation reflect deposition in a bathymetric trough. However, rock units 2 and 3 of the Devonian part of the Road River Formation, in places, contain considerable interbedded clastic and argillaceous limestone with abundant shelly benthonic fossils which reflect marked shallowing of the troughs at these times.

A.W. Norris (1985) reviewed the very rich Silurian and Devonian brachiopod, coral, graptolite and conodont faunas from the Road River Formation described by numerous workers. The succession of Lower Devonian brachiopods occurring in the Road River Formation at the headwaters of Royal Creek are indicated on Figure 7.2.

Lenz (1969) recorded the lowest Lochkovian index graptolite, *Monograptus uniformis uniformis* Pribyl, and the index trilobite, *Warburgella rugulosa* from the Road River Formation at a section on Hart River (65°37′36″N, 136°45′00″W).

Conodonts indicative of the conodont *pesavis* Zone of Fåhraeus (1971) are associated with brachiopods of the *Spirigerina supramarginalis* unit of Lenz (1977a, p. 42), and with the upper Lochkovian index graptolite *Monograptus hercynicus* Perner at Royal Creek.

The Pragian index graptolite, *Monograptus yukonensis*, occurs in the upper part of the brachiopod *Davidsoniatrypa johnsoni* unit. Conodonts from this faunal unit are aligned with faunas 5 and 6 of Klapper et al. (1971, p. 289, fig. 1) which were later equated with the *sulcatus* and *kindlei* zones (Klapper, 1977, p. 35; Lane and Ormiston, 1979, p. 45).

Conodonts associated with the *Sieberella* cf. *webbi–Nymphorhynchia pseudolivonica* fauna of Lenz (1977a) are aligned with the *dehiscens* Zone by Klapper (1977).

The highest condonts recovered from the upper part of the Road River Formation above the brachiopod *S.* cf. *webbi–N. pseudolivonica* fauna at the headwaters of Royal Creek are aligned with the *gronbergi* and *inversus* zones (Klapper, 1977, fig. 2, p. 35), although the *gronbergi* Zone has not been recognized in the northern Yukon Territory.

Uyeno and Mason (1975, p. 716, 717) described conodonts indicative of the *inversus* and *costatus* zones from beds of the Road River Formation outcropping on Road River at 66°35′N, 135°35′W. The *inversus* Zone at this locality is associated with the echinoderm ossicle, *Gasterocoma*? *bicaula*, and was recorded 82 to 84.1 m above beds bearing *Monograptus yukonensis*. This zone indicates correlation with the lower parts of the Ogilvie and Cranswick formations. The *costatus* Zone was recorded from 133.2 m above beds bearing *M. yukonensis* and indicates correlation with the upper part of the Cranswick Formation and the lower part of the Hume Formation.

Michelle Formation

The name Michelle Formation was introduced by A.W. Norris (1968b, p. 16) to apply to a relatively thin but distinct rock unit consisting mainly of argillaceous limestone and shale that overlies shale of the Road River Formation and underlies carbonate of the Ogilvie Formation. The type section (Section 14) is located near Hart River in northern Ogilvie Mountains (Fig. 7.1).

The Michelle Formation is developed in the southwestern part of the report area within the Blackstone Trough. It varies in thickness from a minimum of 56 m at Section 21 in Nahoni Range to a maximum of 187 m at Section 19 on Blackstone River.

Rocks of the Michelle Formation mainly consist of dark grey calcareous shale, and richly fossiliferous, dark grey, micritic, platy to thick bedded argillaceous limestone that weathers orange-brown. In places, dolomite and silty, argillaceous dolomite that weather brownish grey occur in the upper part of the formation. In addition, some of the the beds are fetid, and most contain a large amount of organic material, evident in insoluble residues after acid treatment.

The level where argillaceous limestone becomes the dominant lithology was selected as the gradational lower contact with shale of the Road River Formation (Fig. 7.8; A.W. Norris, 1968b, p. 16). The upper contact with the more resistant, lighter coloured carbonate of the Ogilvie Formation is abrupt and possibly disconformable, but faunal evidence suggests that if there is a hiatus between the two formations it is of short duration.

Some of the fossil groups present in the Michelle Formation have been studied in detail. These include brachiopods (Ludvigsen, 1970), trilobites (Ormiston, 1971), ostracodes (Copeland, *in* Ludvigsen, 1970), nautiloids (Collins, 1969), and stromatoporoids (Stearn and Mehrota, 1970).

Ludvigsen (1970) concluded that brachiopods of the Michelle Formation correlate with the *Eurekaspirifer*

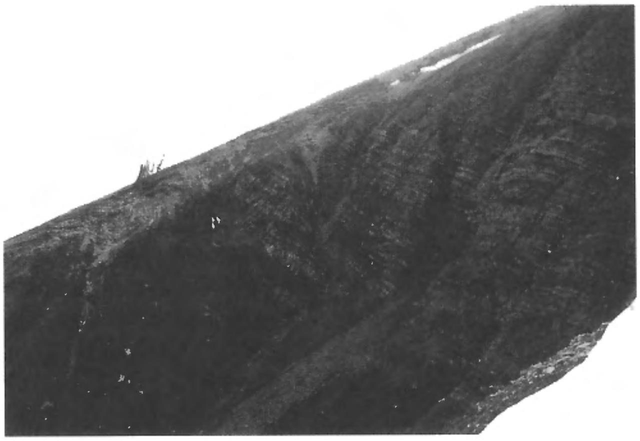

Figure 7.8. *Close-up view of the contact between the upper part of the graptolitic shale of the Road River Formation and the lower part of the interbedded argillaceous limestone, limestone, and shale of the Michelle Formation. Section 16 at approximately 65°27.5′N, 137°02′W, about 1.6 km east of Hart River in the Ogilvie Mountains. GSC photo 1991–080–A.*

pinyonensis Zone of Nevada, dated as early Emsian (late Early Devonian).

Ormiston (1971) indicated that the affinities of the trilobites are with forms in Emsian beds of the Arctic Islands and Alaska, with the qualification that no forms suggest a late Emsian age.

Fåhraeus (1971) concluded that the conodont fauna of the Michelle Formation belonged to the upper part of the *dehiscens* Zone of early Emsian (late Early Devonian) age.

Copeland (*in* Ludvigsen, 1970) indicated that the ostracode fauna of the Michelle Formation is very simlar to that illustrated by Berdan (*in* Churkin and Brabb, 1968) from the Limestone and shale member of the McCann Hill Chert of east-central Alaska.

The echinoderm ossicles with double and cross-like axial canals, assigned to *Gasterocoma*? *bicaula* Johnson and Lane (1969), first appear in the Michelle Formation, but are exceedingly rare. In the report area, *G.*? *bicaula* first appears in abundance in the lower part of the Ogilvie Formation and equivalent beds.

Cranswick Formation

The name Cranswick Formation was introduced by A.W. Norris (1968b, p. 27) for Devonian limestone and shale that overlie dolomite of the Unnamed carbonate unit and, in the type area (Section 6), underlie a tongue of the Road River Formation. At Section 4, near the headwaters of Cranswick River, the Cranswick Formation is overlain by a tongue of the Mount Baird Formation (A.W. Norris, 1985, figs. 2, 4).

The Cranswick Formation is developed on the Mackenzie Platform and in Cambell Uplift. It is approximately equivalent to the upper pellet limestone of the Gossage Formation of Tassonyi (1969), and the Landry Formation of Pugh (1983). The Cranswick Formation also replaces the Ogilvie Formation, as defined by A.W. Norris (1967, 1968a, b), in sections east of the Richardson Trough.

Thickness of the Cranswick Formation varies from 120 m at the type section immediately west of Snake River, to 555 m at Section 4 near the headwaters of Cranswick River.

The Cranswick Formation at the type section consists of two parts: a lower unit (63 m thick) of medium brownish grey to black, aphanitic to fine grained, thin bedded to massive limestone, and an upper unit (57 m thick), of black, fine grained limestone and argillaceous limestone, interbedded with black calcareous shale. At Section 4, nodular chert occurs in limestone beds in the lower quarter, near the middle, and in the upper third of the formation.

The lower contact of the Cranswick Formation in the type area is with dolomite of the Unnamed carbonate unit (Fig. 7.4). In Campbell Uplift, the Cranswick Formation unconformably overlies Silurian dolomitic rocks assigned to the Vunta Formation by Norford (1964).

The upper contact of the Cranswick Formation in the type area is with a tongue of black bituminous and calcareous shale of the Road River Formation. At Section 4, near the headwaters of Cranswick River, the upper contact is with a tongue of greenish grey calcareous shale of the Mount Baird Formation. On the southern flank of Campbell Uplift, the Cranswick Formation is unconformably overlain by a thin wedge of clastic rocks of the Upper Devonian Imperial Formation.

A large part of the fossiliferous limestone of the Cranswick Formation suggests deposition under open marine, subtidal, low-energy conditions. The aphanitic limestone and some dolomite in the basal part of the formation at Sections 4 and 2a, suggest restricted marine conditions for that part of the sequence.

The more diagnostic megafossils from the lower unit of the Cranswick Formation at the type section include the following (Pedder and Klapper, 1977, p. 231, 233): *Spongonaria* sp. cf. *S. richardsonensis* Crickmay, *Planetophyllum* sp., *Carinatina lowtherensis* Johnson and Boucot, and *Gasterocoma*? *bicaula* Johnson and Lane. Megafossils from the upper unit of the Cranswick Formation at the type section include numerous dacryoconarid tentaculitids, some trilobites and a few *Gasterocoma*? *bicaula* and cf. *Foordites* sp. Conodonts throughout most of the Cranswick Formation at the type section are assignable to either the *gronbergi* or *inversus* zone, and higher beds are referred to the *serotinus* Zone (Pedder and Klapper, 1977, p. 233).

A.E.H. Pedder (GSC Internal Report No. AWN-95-AEHP-1979) identified corals from the Cranswick Formation at Section 4 including: *Spongonaria* sp. cf. *S. richardsonensis* Crickmay from several levels between 297 and 353 m above the base of the formation, and *Roemeripora spelaena* (Etheridge) from a number of levels between 361 and 485 m above the base of the formation. The latter fossil has also been noted in drill cores of the Cranswick Formation in the subsurface of the Mackenzie Platform.

Conodonts indicative of the *inversus* Zone, identified by T.T. Uyeno (GSC Internal Report No. 3-TTU-1977), and associated with megafossils have been recovered from the lower part of the Cranswick Formation exposed in a quarry on the Dempster Highway, near the north end of Campbell Lake (D.K. Norris and Calverley, 1978, p. 59, fig. 31). The *inversus* Zone indicates a mid Emsian (late Early Devonian) age, and correlation with the lower part of Ogilvie Formation west of the Richardson Trough.

Conodonts suggestive of the *australis* Zone, from the upper part of the Cranswick Formation at Section 31 on the east side of Campbell Lake, have been reported by Uyeno and Mason (1975, p. 715). These are dated as mid Eifelian (early Middle Devonian), and indicate correlation with the lower part of the Hume Formation in the Powell Creek area.

Ogilvie Formation

The Ogilvie Formation was introduced by A.W. Norris (1968b, p. 28) as a Devonian carbonate unit overlying the Kutchin Formation in northwestern Ogilvie Mountains, or the Michelle Formation in the Hart-Blackstone-Ogilvie rivers area, and underlying the Unnamed shale unit or clastic and carbonate rocks of Carboniferous age. The Ogilvie Formation is a carbonate shelf deposit that occurs on the Yukon Stable Block west of the Richardson Trough, and on White Mountains Platform at the north end of the Richardson Trough.

The maximum measured thickness is 1350 m, measured at Section 19 (A.W. Norris, 1985, fig. 5) near the junction of the Blackstone and Ogilvie rivers. However, fossils suggest that part of this section may be repeated by faulting. The Ogilvie Formation is between 610 and 915 m thick in the subsurface of Eagle Plain, and mainly less than 610 m thick in the outcrop belts to the south and west. Plotted sections show that the thickness of the Ogilvie Formation is approximately inversely proportional to the thickness of the overlying Unnamed shale unit.

The Ogilvie Formation consists mainly of medium brown to grey, aphanitic to fine grained, thin bedded to massive, resistant, cliff-forming limestone, weathering light to medium grey (Fig. 7.9). Beds of coarser grained encrinite, some of which are fetid, occur at scattered intervals. Some darker carbonate beds contain argillaceous and silty material. Scattered chert is also present in a few sections and is most common in the upper part of the formation. In the Hart-Blackstone rivers area, dolomitized beds occur in the lower one quarter to one third of the formation, and in the southern Nahoni Range, dolomite occurs in the lower two thirds of the formation.

Figure 7.9. *Vertically dipping limestone beds of the Ogilvie Formation, exposed along the Ogilvie River on the Dempster Highway (196 km from the southern origin). ISPG photos 1855-54, 2049-143.*

The lower contact of the Ogilvie Formation in the northern Ogilvie Mountains is with the Kutchin Formation (Fig. 7.3), or with Lower Ordovician strata where the Kutchin is missing (Ludvigsen, 1980). The lower contact in the Hart–Blackstone–Ogilvie rivers area is with the Michelle Formation, where faunal evidence suggests that the contact is probably conformable.

The upper contact of the Ogilvie Formation is with the Unnamed shale unit. Fossils and thickness data from both these rock units indicate that the contact is highly diachronous.

The following conodont zones, in ascending order, have been recognized in the Ogilvie Formation (Klapper, *in* Perry et al., 1974; Klapper, 1977): *inversus* and possibly older *gronbergi* zones; *serotinus* Zone that correlates with the brachiopod *Elythyna* fauna of Nevada; *costatus* Zone; *Polygnathus pseudofoliatus* faunal unit, which may correlate with either the *australis* or *kockelianus* zones; and an undifferentiated *varcus* Zone.

Brachiopods from the Ogilvie Formation studied by Perry (1971; Perry et al., 1974) were assigned to the lower Emsian, Emsian to lower Eifelian, Eifelian, *Warrenella kirki*, and *Leiorhynchus castanea* zones; and the stringocephalids were assigned to the Givetian. At Section 24 on Mount Burgess, stringocephalids occur in scattered beds in a 311 m interval within the upper part of the formation (A.W. Norris, 1968b, 1985, fig. 7).

Some of the more diagnostic corals in the Ogilvie Formation identified by Pedder (*in* Perry et al., 1974) include: *Martinophyllum* sp., suggestive of an Emsian age; *Spongonaria filicata* Crickmay, *S. excavata* (Crickmay), *S. philoctetes* Crickmay, *S. ogilviensis* Crickmay, "*Hexagonaria*" sp. ex gr. *smithi* Pedder, and *Embolophyllum* cf. *aequiseptatum* (Hill), assigned to the upper Emsian; *Taimyrophyllum* sp., assigned to the upper Emsian–lower Eifelian; and *Radiastraea* cf. *verrilli* (Meek), indicative of an Eifelian age and which suggests a correlation with part of the Hume Formation. An important Givetian coral associated with the stringocephalids is *Dendrostella trigemme* (Quenstedt).

The numerous trilobites in the Ogilvie Formation identified by Ormiston are listed in A.W. Norris (1968a, b) and Perry et al. (1974).

The goniatite *Cabrieroceras* cf. *karpinskyi* Holzapfel has been recorded by Perry et al. (1974) from near the top of the Ogilvie Formation at their Section S-5 (65°28′N, 138°15′W) and indicates a late Eifelian age.

The distinct echinoderm ossicles, *Gasterocoma*? *bicaula* Johnson and Lane, are widely distributed in the lower Ogilvie Formation and equivalent beds. The range of these forms is from the *dehiscens* to the lower part of the *costatus* zones (A.W. Norris, 1985, fig. 3).

Where the lower part of the Ogilvie Formation is variably dolomitized, the large ostracode, *Moelleritia canadensis* Copeland, is generally the only megafossil present.

Unnamed shale unit

The informal designation Unnamed shale unit is used in the same sense here as when it is used by A.W. Norris (1967, 1968a, b). It is approximately equivalent to the upper member of the McCann Hill Chert of Alaska, but in the Yukon Territory it may include younger Devonian and Mississippian shale units. The name McCann Hill Chert was introduced by Churkin and Brabb (1965, p. 180–182) for a sequence consisting of limestone and shale in its lower part, and siliceous shale, chert, siltstone, and cherty grit in its upper part. At the type section in the Nation River area of east central Alaska, the McCann Hill Chert overlies shale of the Road River Formation and underlies greywacke, chert conglomerate and silty shale of the Nation River Formation. More recent work in the area by Blodgett (1978) shows that the lower member of the McCann Hill Chert changes into a limestone which is continuous with the Ogilvie Formation in adjacent Yukon Territory. Where this occurs, the Ogilvie Formation is overlain by the upper Chert and shale member of the McCann Hill Chert.

In the report area, the Unnamed shale unit applies to a recessive interval of several types of shale that overlies the highly diachronous top of the Ogilvie Formation, and underlies relatively resistant clastic and carbonate rocks of Mississippian and younger age. The Unnamed shale unit appears to have approximately the same distribution as the underlying Ogilvie Formation in the southwestern part of the report area, although exposures of the unit are generally poor and incomplete. In the Mount Burgess area (Section 24; A.W. Norris, 1985, fig. 7), on the east flank of the Dave Lord High, the unit is very thin or missing.

A relatively complete sequence of the Unnamed shale unit is exposed at Section 46 (A.W. Norris, 1985, fig. 5) where it consists of: a lower unit (143 m thick) of black, silvery grey weathering, hard, highly fissile, noncalcareous, siliceous shale, associated with some thin and even bedded black chert; and a more resistant, upper unit (79 m thick) of thin bedded, black, micritic and argillaceous limestone, some black, fissile, calcareous shale, and minor, thin bedded, cherty limestone. At some sections, notably 18 and 23a (A.W. Norris, 1985, fig. 5), parts of the dark, noncalcareous shale have been altered to a brick red colour.

The thickness of the Unnamed shale unit in the outcrop belt varies from a minimum of 171 m to a maximum of 323 m.

The upper contact of the Unnamed shale unit at Section 18 (A.W. Norris, 1985, fig. 5) in the Ogilvie Mountains, between Hart and Blackstone rivers, is at the base of hard beds of silty shale, chert and cherty limestone containing fossils dated as late Mississippian (Chesterian) by E.W. Bamber (*in* A.W. Norris, 1968b, p. 39). The upper contact at Section 22 on the east flank of Nahoni Range, is drawn between bluish grey and silvery grey weathering siliceous shale of the Unnamed shale unit, and cherty carbonate beds of Carboniferous (Visean) age (E.W. Bamber, *in* A.W. Norris, 1968b, p. 40).

Conodonts indicative of the Middle Devonian *australis* or *kockelianus* zones were recorded by Lane and Ormiston (1979, p. 50) from the lower member of the McCann Hill Chert. Indeterminable plant fragments, and spores dated as Upper Devonian, were recorded by Churkin and Brabb (1965, p. 181) from the upper shale and chert member of the McCann Hill Chert.

Very few fossils have been recovered from the Unnamed shale unit of the report area. Tentaculitids, suggestive of the *Nowakia holynensis* Zone, from the lower part of the unit at three sections in the southwestern part of the area, have been reported by Perry et al. (1974, p. 1058, 1093, 1094). Lütke (1979) aligned the base of the *holynensis* Zone with the upper part of the conodont *serotinus* Zone.

The goniatite, *Agoniatites* sp. cf. *A. fulguralis* (Whidborne), has been reported by House and Pedder (1963, p. 501, 509, 510) from beds of the Unnamed shale unit at a section on Ogilvie River at 65°20′N, 138°44′W, which indicates a Givetian (late Middle Devonian) age.

Poorly preserved plant fragments and extremely corroded spores have been recovered from scattered levels of the Unnamed shale unit. The spores are long ranging but do indicate a Devonian age (D.C. McGregor, *in* A.W. Norris, 1985).

Mount Baird Formation and Tongue

The name Mount Baird Formation was introduced by A.W. Norris (1985) to apply to a succession consisting mainly of calcareous shale overlying a tongue of the Road River Formation and underlying the Canol Formation. The type section (Section 6; Fig. 7.10) located at the Mackenzie Mountain front immediately west of Snake River, is that described by A.W. Norris (1968b, p. 35, 36, figs. 4-6), which was formerly referred to as the Hare Indian Formation for lack of a better name.

The Mount Baird Formation occupies a narrow belt along the southeastern flank of the Richardson Anticlinorium and represents a transitional facies between a carbonate platform succession to the east and a dark shale basin succession to the west.

The thickness of the formation in the type area is about 590 m, and this represents its maximum development. At the type section, the lithology consists of predominantly dark greenish grey, calcareous shale that weathers orange-brown. Four thin sequences of resistant, thin bedded, rubbly, argillaceous, micritic limestone occur in the succession, two in the lower one fifth, and two in the upper one quarter of the section; these are fossiliferous.

At Section 4 at the headwaters of Cranswick River, where the formation is truncated by faulting and overlies the Cranswick Formation, it consists of black calcareous shale that weathers orange-brown.

Figure 7.10. *View northeastward showing part of the Cranswick Formation along and just above the creek gully, overlain by a thick succession of calcareous shale and limestone of the Mount Baird Formation. Section 6 at 65°27–27.5′N, 133°34–35′W, immediately west of Snake River and immediately north of the Mackenzie Mountain front. GSC photo 1991-080-D.*

At Section 6, the contact between calcareous shale of the Mount Baird Formation and the underlying tongue of the black, noncalcareous shale of the Road River Formation is sharp but apparently conformable. At the headwaters of Cranswick River, the Mount Baird Tongue conformably overlies resistant, cherty limestone beds of the Cranswick Formation (A.W. Norris, 1968b, Pl. 2).

The upper contact between the Mount Baird Formation and overlying dark shale of the Canol Formation at Section 6 is disconformable on the basis of fossils, and marks a significant hiatus.

An abundant and highly varied megafauna occurs in the Mount Baird Formation. With the exception of some species of the brachiopods *Warrenella* and *Spinatrypina*, and some trilobites, the bulk of this megafauna has not been described. The brachiopods *Warrenella crickmayi* Ludvigsen and Perry (1975) and *Warrenella weigelti meeki* Ludvigsen and Perry (1975) are from the upper part of the formation from two localities near the type section. *Spinatrypina (Spinatrypina) edmundsi* Copper (1979) is from about 20 m above the base of the Mount Baird (Hume) Formation on Snake River. Trilobites identified by A.R. Ormiston (*in* A.W. Norris, 1968b, p. 38) from the type section of the Mount Baird Formation comprise *Dechenella* (*D.*) sp. cf. *D.* (*D.*) *maclareni* Ormiston and *Dechenella* (*D.*) *paragranula* Ormiston. All of the above fossils indicate an Eifelian (early Middle Devonian) age.

Nucleospira sp. occurs near the top of the Mount Baird Formation, which suggests correlation with the upper part of the Hume Formation to the east (Hogg, 1965).

Hume Formation

The name Hume Formation was introduced by Bassett (1961, p. 486) for the succession of argillaceous limestone and shale that overlies the Bear Rock Formation and underlies the Hare Indian Formation. The type section is on the east branch of Hume River at the front of the Mackenzie Mountains at 65°20′30″N, 129°58′00″W.

In the subsurface, the Hume Formation can be traced from the type area across a large part of the Mackenzie Platform (Tassonyi, 1969), and in outcrops it can be traced westward along the front of the Mackenzie Mountains to the Arctic Red River area (A.W. Norris, 1968b). Beyond the Arctic Red River area, equivalents of the Hume Formation are recognized in the Cranswick and Mount Baird formations.

The thickness of the Hume Formation varies from 122 m at the type locality to 168 m in the central Mackenzie River region (Bassett, 1961, p. 487). In outcrops along the front of the Mackenzie Mountains, from just within and outside the southeast corner of the report area, the thickness varies from 121 m at Section 2 to 231 m at Section 3 (A.W. Norris, 1985, fig. 4).

Tassonyi (1969, p. 64–69) designated the Imperial Loon Creek No. 2 well (65°07′20″N, 126°28′51″W) as a supplementary subsurface reference section for the Hume Formation, and recorded three informal rock units within it: a lower unit of brown bioclastic limestone, calcareous shale, and argillaceous limestone (38.1 m thick); a middle unit of greenish grey calcareous shale, and argillaceous and silty fossiliferous limestone (18.3 m thick); and an upper unit of brown micritic and argillaceous limestone and fine bioclastic limetone (60 m thick).

The lithology of the Hume Formation in outcrops at Sections 1, 2, 2a and 3 (A.W. Norris, 1985, fig. 4) consists of richly fossiliferous, black, nodular, irregularly and evenly bedded limestone, argillaceous limestone that weathers brownish grey, and dark, fissile, in part furruginous, noncalcareous shale (A.W. Norris, 1968b, p. 33).

At many localities in the central Mackenzie River region the contact between the Hume Formation and underlying Bear Rock Formation is sharp and probably disconformable according to Bassett (1961, p. 487). However, at other localities, a transition zone separates the two formations, and where this occurs, both Bassett and Tassonyi (1969, p. 65, 66) selected the contact at the top of the mixed lithologies.

At Sections 2 and 3 (A.W. Norris, 1985, fig. 4), the lower contact is between recessive, argillaceous limestone and shale of the Hume Formation and underlying resistant, micritic limestone of the Cranswick Formation.

At Section 1 (A.W. Norris, 1985, fig. 4), immediately east of Arctic Red River, the Hume Formation is overlain by a truncated argillaceous coquina bed (0.6 m thick), consisting of *Leiorhynchus castanea* (Meek) and other fossils of the basal Hare Indian Formation, which is, in turn, sharply and disconformably overlain by the Canol Formation (A.W. Norris, 1968b, p. 33). To the west, at Sections 2 (Fig. 7.11), 2a and 3, the coquina bed is missing and

Figure 7.11. Resistant beds of the Hume Formation unconformably overlain by black shale of the Canol Formation. Section 2 at approximately 65°23′N, 131°20′W, on the tributary stream immediately west of Arctic Red River. GSC photo 1991-080-J.

the Canol Formation rests disconformably on various beds of the Hume Formation.

The Hume Formation contains a varied and abundant fauna within which two broad megafaunal associations are recognized: a lower *Eoschuchertella adoceta* Zone of Crickmay (1960, p. 1); and an upper *Carinatrypa dysmorphostrota* Zone of Pedder (1975, p. 572), which is approximately equivalent to the *Radiastraea verilli* Zone of Crickmay (1960) and the "*Spinulicosta*" *stainbrooki* Fauna of Caldwell (1971).

Conodonts from the *australis* and *kockelianus* zones have been recognized by Uyeno (1979, p. 236-238) in the Hume Formation of the Powell Creek area, indicating an Eifelian (early Middle Devonian) age.

Megafossils assignable to the *Carinatrypa dysmorphostrota* Zone have been recovered by A.W. Norris (1968b, p. 34, 35) from the Hume Formation at Sections 1 and 2 (A.W. Norris, 1985, fig. 4).

Hare Indian Formation

The name Hare Indian Formation, as used by Bassett (1961, p. 490-492), applies to the predominantly shale sequence that overlies carbonate of the Hume Formation, and underlies carbonate of the Ramparts Formation, or dark shale of the Canol Formation where the Ramparts is not developed. A completely exposed type section of this unit was selected by Hume and Link (1945, p. 20) in the Imperial Range on Mountain River.

The Hare Indian Formation is recognized throughout the Norman Wells-Fort Good Hope area, and extends as far north as the Anderson River area. Northwest and west of Norman Wells it has been truncated by pre-Canol erosion so that it is missing in the Richfield et al. Point Separation No. 1 well (67°34′06″N, 134°00′10″W), and is represented by an erosional remnant at Section 1 immediately east of Arctic Red River (A.W. Norris, 1985, fig. 4).

Two distinct shale units were recognized by Bassett (1961) and Tassonyi (1969) in the Hare Indian Formation of the type area. The lower, thinner part of the formation, is referred to informally by Tassonyi (1969, p. 71) as the spore-bearing member, and by some workers (e.g., Pugh, 1983) as the Bluefish Member. It consists of very dark brownish grey or black, bituminous, in part noncalcareous and calcareous, shale. The upper unit of the formation consists of predominantly dark grey calcareous shale with generally less than 10 per cent interbedded calcareous siltstone and argillaceous or silty limestone.

The erosional remnant of the Hare Indian Formation at Section 1 near Arctic Red River, consists of dark grey, evenly and irregularly thin bedded, slightly argillaceous, richly fossiliferous limestone that weathers pale brown, and is stained rusty brown in places (A.W. Norris, 1968b, p. 90).

The contact of the Hare Indian Formation with the underlying Hume Formation is described by Bassett (1961, p. 490) as being sharp but conformable. Where this contact is gradational, it is apparent that different workers have selected different levels at the base or top of the transition zone. The contact of the Hare Indian Formation with the overlying Ramparts Formation is generally sharp in the Norman Wells area, but is transitional at other localities. Where the limestone of the Ramparts Formation has not developed, the shale of the Hare Indian Formation is sharply overlain by shale of the Canol Formation.

A varied and abundant megafauna occurs in the Hare Indian Formation some of which has been described by numerous workers. The megafaunas recognized by Caldwell (1971, p. 6, 7) are as follows, in ascending order: *Leiorhynchus castanea*, "*Emanuella*" *meristoides*, and *Rhyssochonetes aurora*. A detailed discussion of these faunas is given by A.W. Norris (1985, p. 29).

A very abundant *castanea* fauna, recorded by A.W. Norris (1968b, p. 37), occurs in the erosional remnant of the basal Hare Indian Formation at Section 1.

Conodonts identified by Uyeno (1978, p. 238) from the upper part of the Hare Indian Formation at Powell Creek are assigned to an undifferentiated *varcus* Zone. Conodonts associated with the *Rhyssochonetes aurora* fauna of Caldwell (1971, p. 6) or the *Ectorensselandia laevis* Zone of Pedder (1975, p. 573) are assignable to the Middle *varcus* Subzone.

Canol Formation

The name Canol Formation was introduced by Bassett (1961, p. 494) to apply to the black shale that overlies the Kee Scarp Formation (Ramparts Formation of Tassonyi, 1969), and the Hare Indian Formation where the Kee Scarp is missing. At the type section of the Canol Formation on the northwest side of Powell Creek at the front of the Mackenzie Mountains (65°16′30″N, 128°46′30″W), it consists of 23 m of dark grey to black, noncalcareous, soft to very hard shale, in part covered with a greenish and yellowish weathering patina. At this locality, it overlies cherty and shaly limestone beds of the Ramparts Formation, and underlies soft black shale of the Imperial Formation (Tassonyi, 1969, p. 90). From the type area, the Canol Formation can be traced westward along the Mackenzie Mountain front to the Snake River area, and along the east and west flanks of the Richardson Anticlinorium. Still farther west, the Canol Formation becomes indistinguishable from the upper part of the Unnamed shale unit, and the upper part of the upper, chert and shale member of the McCann Hill Chert of east-central Alaska and adjacent Yukon Territory. Where the Canol Formation becomes predominantly silty and sandy, it has been included in the Imperial Formation.

Based on regional evidence, the shale that outcrops along the mountain front between Blackstone and Hart rivers, designated as the "Canol" Formation by Dubord et al. (1986), is actually the Unnamed shale unit. The Canol Formation, as mapped by Cecile et al. (1982) along the northwestern flank of the Richardson Anticlinorium, includes interbedded chert and shale that belong in the uppermost member of the Road River Formation.

The lithology of the Canol Formation from the type area westward to the southeastern part of the report area is relatively uniform. In the report area, it contains scattered, orange weathering, carbonate(?) nodules and some small nodules of pyrite. Westward from Section 11, near Little Wind River, at the southwest end of the Richardson Anticlinorium, the Canol Formation becomes lighter in colour due to the addition of increasing amounts of siltstone and sandstone.

The three informal members of Tassonyi (1969, p. 92) in the type area are not recognizable in the Canol Formation of the report area. Moreover, contrary to Muir et al. (1984) and others, there is absolutely no evidence to indicate that the Canol Formation intertongues with any part of the underlying Ramparts (Kee Scarp) Formation. All surface and subsurface sections show the Canol Formation onlapping different beds of different ages at different places, indicating a regional unconformity at its base (Braun et al., 1989). In the report area, the Canol Formation unconformably overlies an eroded remnant of the Hare Indian Formation, various beds of the Hume Formation, the Mount Baird Formation, or various beds of the Road River Formation. The hiatus separating the base of the Canol Formation from underlying beds is greatest in the southeastern part of the report area.

The contact between the Canol Formation and the overlying Imperial Formation in the report area is marked by an abrupt change from black shale of the Canol Formation to greenish grey siltstone and sandstone, interbedded with nonbituminous and nonsiliceous brownish grey shale of the Imperial Formation. This contact, although sharp, appears to be conformable.

Conodonts dated by Uyeno (*in* Braun et al., 1989, p. 104) from limestone concretions in the lower part of the Canol Formation at Powell Creek (65°16′30″N, 128°46′57″W) are placed in the Lower *asymmetrica* Zone. At Hume River (65°20′N, 129°57′W), Uyeno (op. cit.) indicated that the basal Canol Formation could extend into the Lowermost *asymmetrica* Zone.

From the report area, shield-shaped markings (anaptychi or spathiocarids), similar to those occurring in the Norman Wells area, were recovered from the Canol Formation at Section 1; from a locality at 65°17′N, 135°45′W beween Sections 10 and 11; and from Canol-like beds in the upper part of the Unnamed shale unit in the North Cathedral Y.T. B-62 well (66°11′13.5″N, 138°41′53″W) west of the Richardson Anticlinorium (A.W. Norris, 1985).

A conodont assemblage, including *Palmatolepis*, was recorded by Bassett and Stout (1968, p. 744) from the Canol Formation outcropping at 65°54′N, 135°56′W on Peel River. The presence of the genus *Palmatolepis* indicates an assignment to the *disparilis* (late Givetian) or younger Zone.

Palynomorphs indicating a late Givetian or more probably an early Frasnian age were identified by D.C. McGregor from the Canol Formation at Section 35 on Trail River (A.W. Norris, 1985, fig. 8).

Imperial Formation

The name Imperial Formation, as modified by Bassett (1961), applies to the sequence of Upper Devonian clastic rocks and minor interbedded limestone that overlies the Canol Formation and is unconformably overlain by Cretaceous rocks throughout a large part of the central and lower Mackenzie River region. The complete Imperial sequence, in the sense of Bassett (1961), is well exposed on the northeast flank of Imperial Anticline on Imperial River.

Within the report area, clastic rocks of the Imperial Formation crop out along the front of the Mackenzie Mountains, along the eastern, northern (Fig. 7.12) and western flanks of the Richardson Anticlinorium, along the northern flank of the Wernecke Mountains, and form the bedrock surface of a large area south of the Mackenzie River Delta and Campbell Uplift.

The thickness of the Imperial Formation at the type section is 716 m (Tassonyi, 1969, p. 96). Representative thicknesses within and near the report area include: 537 m at Section 1 near Arctic Red River (the formation is incomplete); 1377 m at Section 35 on Trail River; 1137 m at Section 11 on upper Prongs Creek; and 988 m at Section 12 near Clear Creek (A.W. Norris, 1985).

Figure 7.12. Interbedded siltstone and shale of the Imperial Formation exposed along Dempster Highway (488 km from the southern origin) at "Vittrekwa Pass", at approximately 67°10′N, 135°53′W. ISPG photo 1855-44.

The lithology of the lower 422 m of the type section of the Imperial Formation on Imperial River consists of five coarsening-upward sequences, with each sequence capped with fossiliferous sandstone and argillaceous limestone (Chi and Hills, 1973, p. 243). The remaining part of the section is described as soft, dark grey-green shale with a few thin beds of very fine grained sandstone and siltstone.

Detailed petrography of samples from the type section of the Imperial Formation was done by Robbins (1960).

The Imperial Formation at Section 1 (Fig. 7.13) near Arctic Red River has been described by A.W. Norris (1968b, p. 43, 44, fig. 3, Pl. 12), Hills and Braman (1978), and Braman (1981, p. 18-20). The lithology of the lower 108 m of this section exhibits many features typical of turbidites. A 272 m thick medial sequence contains a few zones of turbidite beds, and the upper part of the section is closely comparable lithologically to the type Imperial Formation to the east.

The lithology of the Imperial Formation at Section 35 on Trail River (A.W. Norris, 1985) consists of the following, in ascending order: Unit 1, 428 m thick, consists of alternating dark grey shale, dark grey silty shale, and dark greenish grey, silty, argillaceous and sericitic, fine grained sandstone. The lower 122 m of this unit is highly ferruginous, and some of the sandstone beds are crosslaminated and exhibit flow-cast structures (Fig. 7.14). Unit 2, 354 m thick, consists of soft, dark grey, fissile shale, with widely spaced thin beds of siltstone, and scattered nodules of clay ironstone, as well as thin beds of argillaceous and silty

Figure 7.13. Siltstone, shale and sandstone of the Imperial Formation exposed on a south-facing mountain slope, underlain by black shale of the Canol Formation exposed in left foreground. Section 1, 19 km east of Arctic Red River at approximately 65°25′N, 130°45′W. GSC photo 1991-080-E.

Figure 7.14. "Tool" marks in the flyshoid Imperial Formation outcropping on the southeast flank of Campbell Uplift at 68°11′N, 133°26′W. ISPG photo 2049–27.

sandstone which are more closely spaced in the upper third of the unit. Unit 3, 254 m thick, consists of greenish grey, silty and argillaceous, fine grained quartzose sandstone, some beds of which are cross-laminated and contain macerated plant fragments, and dark grey to black fissile shale which in places contains thin interbeds of argillaceous sandstone. Unit 4, 201 m thick, consists of dark grey to black, ferruginous shale, and widely spaced, resistant, evenly thick bedded sandstone that weathers medium brown and orange.

The contact of the Imperial Formation with the underlying shale beds of the Canol Formation is relatively easy to recognize throughout the eastern and southeastern parts of the area. Where the Canol Formation becomes silty and lighter in colour, as in the southwestern part of the area, distinguishing this boundary becomes less certain.

East of the report area, the Imperial Formation is overlain by basal Cretaceous sandstone and conglomerate (Bassett, 1961, p. 497). Along the northern flank of the Mackenzie Mountains and the eastern and western flanks of the Richardson Anticlinorium, the Imperial Formation is overlain by conglomeratic sandstone and siltstone designated as the Tuttle Formation by Pugh (1983), or as the Dus map unit by D.K. Norris (1985). Miospore ages (Braman, 1981) indicate that a hiatus separates the top of the Imperial Formation from the base of the Tuttle Formation at Section 35 on Trail River. However, the hiatus may be the result of faulting. A pronounced angular unconformity separates the top of the clastic beds assigned to the "Imperial" Formation and overlying coarsely clastic beds of Permian and younger ages at Sections 33 (Fig. 7.15) and 34 at the north end of the Richardson Anticlinorium.

Megafossils from the Imperial Formation have been listed, described or discussed by numerous workers (A.W. Norris, 1985). An abundant megafauna was recorded by A.W. Norris (1968b, p. 46) from the upper 168 m of exposed Imperial Formation at Section 1. This fauna was dated as early Famennian on the basis of similarity to a fauna from the Arctic Archipelago described by McLaren (*in* Kerr et al., 1965), and similarity to rhynchonellids from the southern District of Mackenzie described by Sartenaer (1969).

Miospores from 688 to 843 m above the base of the Imperial at or near Section 1 were assigned by Braman (1981, p. 66) to the *Vallatisporites anthoideus*-*Grandispora gracilis* (AG) Biozone which he correlated with the Middle–Upper *Palmatolepis triangularis* (F3b) through Middle *Palmatolepis crepida* (Fa1b) conodont zones (A.W. Norris, 1985, fig. 3). This same biozone was recorded by Braman (1981) in Section 35 on Trail River between 1300 and 1505 m above the base of the Imperial Formation.

Figure 7.15. Angular unconformity between beds of sandstone, siltstone and shale of the Upper Devonian Imperial Formation and overlying sandstone beds of Permian age, Sheep Creek at 67°41′N, 136°13′W, near Section 33, northern Richardson Anticlinorium (GSC 117384; A.W. Norris, 1968b, Pl. 11).

From between 843 and 848 m in the Arctic Red River Section 1 and between 1505 and 1675 m above the base of the Imperial Formation on Trail River, Braman (1981) recorded miospores of his *Cornispora varicomata-C. monocornata* (VM) Biozone, which he aligned with the conodont Upper *Palmatolepis crepida* Zone (Fa1b).

Spores identified by D.C. McGregor (*in* A.W. Norris, 1985) from Unit 1, between 268 and 420 m above the base of the Imperial Formation on Trail River, Section 35, were dated as late Givetian or early Frasnian; those from near the top of Unit 4, 1460 m above base of the formation, were dated as late Frasnian or early Famennian. McGregor (op cit.) indicated that all spores recovered from the Imperial Formation are black in colour, indicating that they had undergone severe thermal alternation, especially in the lower part of the formation.

Palynomorphs from beds assigned to the Imperial Formation at Sections 11 and 12, located immediately west of the south end of the Richardson Anticlinorium, and Sections 33 and 34, located at the north end of the Richardson Anticlinorium, are so severely corroded and carbonized that they are not determinable, consequently these beds remain undated.

Poorly preserved spores, which were dated by D.C. McGregor (*in* Norford et al., 1970, p. 8) as late Famennian or more probably "Strunian", have been recovered from the subsurface of the upper part of the Imperial Formation in the Shell Peel River Y.T. I-21 well (66°10′50″N, 134°18′52.18″W).

Conodonts identified by T.T. Uyeno (GSC Internal Report 16-TTU-1974), from a 58 m interval between 40.5 and 98.5 m below the top of the Imperial Formation in the Gulf-Mobil Caribou Y.T. N-25 well (66°14′40″N, 134°50′04″W), indicated a range from the *rhomboidea* to the *styrica* zones of Famennian (late Upper Devonian) age.

Tuttle Formation

The name Tuttle Formation was introduced by Pugh (1983) to apply to an alternating succession of coarse to fine clastic rocks overlying the Imperial Formation and equivalent rocks and unconformably underlying late Paleozoic and Mesozoic rocks in the areas flanking the eastern and western sides of the Richardson Anticlinorium. The type section of the Tuttle Formation selected by Pugh (1983) is the sequence overlying the Imperial Formation and underlying Mesozoic rocks in the Pacific Peel Y.T. F-37 well (66°56′26″N, 134°51′54″W) between 106.7 and 980.2 m depths. In the subsurface of Eagle Plain, on the west side of the Richardson Anticlinorium, coarse clastic rocks of the Tuttle Formation pass southward into much finer clastics of the Ford Lake Shale (Fig. 7.2).

Both the eastern and western flanks of the Richardson Anticlinorium are fault bounded and the greatest thicknesses of the Tuttle Formation are preserved immediately adjacent to these faults on the downthrow sides. Pugh (1983, fig. 18) reports maximum preserved thicknesses of 1100 and 1420 m on the east and west sides, respectively, of the Richardson Anticlinorium. He also suggests that the depocentre of the Tuttle Formation was probably within the Richardson Anticlinorium before it was uplifted and Tuttle rocks removed by erosion. Coarse clasts in the conglomerate consist of predominantly white, buff, grey, yellow, orange and pale green chert. Kaolinite and a micaceous mineral are present in much of the sandstone, siltstone and shale. Seven units of conglomerate, conglomeratic sandstone and sandstone designated as M1 to M7 are recorded by Lutchman (1977) within the formation in the type well. The coarse clastic beds, formerly classified by A.W. Norris (1968b, p. 239-244) as the upper member of the Imperial Formation on Trail River, are now assigned (A.W. Norris, 1985) to the Tuttle Formation of Pugh (1983). The succession is about 355 m thick and consists of the following rock units, in asending order: Unit 1 (25 m thick) consists of resistant, mainly conglomeratic sandstone with interbedded conglomerate beds up to 0.3 m thick. Unit 2 (125 m thick) consists of soft, orange weathering, dark grey shale and closely spaced sandstone beds in the lower part. Unit 3 (54 m thick) is resistant, similar to Unit 1, and consists of conglomeratic sandstone, some sandstone, and minor shale. Unit 4 (151 m thick) consists of an alternating succession of orange weathering, fine to coarse grained sandstone, and dark grey, fissile shale with sandstone laminae.

Units 1 and 3 of this succession are resistant and ridge-forming along the eastern flank of the Richardson Anticlinorium, and appear to correspond to the M-1 and M-2 units of Lutchman (1977, p. 5, 6).

The selection of the lower contact and distinction of the Tuttle Formation from the Imperial Formation was based on the following criteria (Pugh, 1983): the appearance of coarser grained clastic rocks, including conglomerate, conglomeratic sandstone, and coarse grained sandstone; the presence of varicoloured coarse chert conglomerate in the north which becomes finer, better sorted and more quartzose towards the south; the presence of carbonaceous fragments and locally detrital coal; and the complete absence of carbonates.

Miospore data by Braman (1981) show a pronounced hiatus separating the base of the Tuttle Formation from the top of the Imperial Formation on Trail River, but it is not known if this hiatus is local (possibly caused by faulting) or regional.

Inconclusive evidence cited by Pugh (1983), based on palynomorphs in the subsurface of Eagle Plain, suggests that the contact between the Tuttle and Imperial formations is diachronous, being older in the north and younger in the south.

The upper contact of the Tuttle Formation commonly shows pre-Mesozoic erosion or more recent truncation along both flanks of the Richardson Anticliorium. At Section 35 on Trail River, the Tuttle Formation has been truncated by faulting and is in contact with Mesozoic rocks.

Two different modes of origin have been suggested for the Tuttle Formation. Lutchman (1977) interpreted the Tuttle Formation as a southward advancing Mississippian clastic wedge of fluvio-deltaic origin, whereas Hills and Braman (1978) and others have pointed out that the Tuttle Formation on Trail River exhibits many of the features of a marine turbidite sequence.

From a sample 173.7 to 174.7 m above the base of the Tuttle Formation, within Unit 3 on Trail River, D.C. McGregor (*in* A.W. Norris, 1985) identified spores of two ages: the younger spores indicated a range of age from late early to early late Famennian (late Late Devonian), and the older reworked spores in the sample suggested a mid-Frasnian (early Late Devonian) age.

From a sample collected 328 m above the base of the Tuttle Formation, from near the top of Unit 4 at Section 35 on Trail River, D.C. McGregor (*in* A.W. Norris, 1985) dated an assemblage of spores as post-Famennian ("Strunian"; early Tournaisian, Tn1b) in age.

Braman (1981, p. 71–73) established the sequence of biozones in beds assigned to the Tuttle Formation on Trail River. He assigned miospores from the lower 145 m of the formation to *Retispora lepidophyta-Lophozonotriletes triangulatus* (LT) Biozone. The base of this biozone could be uppermost Famennian or middle *Spathognathodus costatus* Zone, and the top could be the middle of Tn1a or near the top of the *S. costatus* Zone. Braman (1981, p. 74, 75) assigned miospores from the succeeding 120 m of Tuttle beds on Trail River to the *Retispora lepidophyta-Vallatisporites pusillites* (LP) Biozone. This biozone is interpreted as within the conodont *Protognathodus* Fauna which extends to the lower Tn1b, a level used to mark the boundary between the Devonian and Carboniferous systems. Miospores from the highest beds of the Tuttle Formation on Trail River were assigned to the *Vallatisporites baffensis-Vallatisporites vallatus* (BV) Biozone. This biozone is probably equivalent to Tn1b or lower Tn2 of the Belgian sequence, or to part of the *Protognathodus* Fauna.

Clastic beds between 213 and 889.4 m in the Shell Peel River Y.T. I-21 well (66°10′37″N, 134°18′51″W) were assigned to the Tuttle Formation by Pugh (1983, fig. 32b). D.C. McGregor (*in* Norford et al., 1970, p. 709) considered the lower 131.1 m to be in part equivalent to the Strunian (uppermost Upper Devonian; post-Famennian and pre-Tournaisian). This lower interval was equated by Pugh (1983, fig. 32b) to the M-4 sandstone unit of Lutchman (1977). McGregor dated spores from higher levels in this well, at 152.4 and 670.6 m above the base of the formation, as probably Tournaisian and early or middle Tournaisian, respectively.

PALEOPHYSIOGRAPHIC SUBDIVISIONS

The paleophysiographic subdivisions (Fig. 7.5) used in the report area are those that influenced the sedimentation and paleogeography during Devonian time. These subdivisions are as follows: Mackenzie Platform, Yukon Stable Block, White Mountains Platform, Royal Mountain Platform, Richardson Trough, Blackstone Trough, Selwyn Trough, Rapid Trough, Hazen Trough, Dave Lord High, Bonnet Plume High, and an area of scattered igneous intrusions of Devonian and older age.

Mackenzie Platform

The Mackenzie Platform, named by Lenz (1972, p. 328), covers a wide area west of the Canadian Shield and east of the Richardson Mountains. The western part of this platform is within the report area where exposures of Devonian carbonates occur along the front of the Mackenzie Mountains and on Campbell Uplift.

Yukon Stable Block

The Yukon Stable Block is a triangular area west of the Richardson Mountains, south of the Old Crow-Babbage Depression of D.K. Norris (1983), and north of and including the northern part of the Ogilvie Mountains. It corresponds approximately to the eastern part of Jeletzky's (1962) Yukon Stable Block.

Superimposed on the platform are the Dave Lord High in the north and the Blackstone Trough in the south, which subdivide the platform into five segments.

White Mountains Platform

The name White Mountains Platform was introduced by A.W. Norris (1985) to apply to the area of carbonate deposition that occurs at the northern end of the Richardson Trough. The area coincides with White Uplift of D.K. Norris (1983) and represents a small locally developed carbonate platform surrounded by basinal shale.

Royal Mountain Platform

The name Royal Mountain Platform was introduced by A.W. Norris (1985) to apply to a small area of carbonate rocks surrounded by basinal shale which is located at the southern end of the Richardson Trough. This area was formerly included by Lenz (1972, fig. 3, p. 328) in the eastern part of the southern segment of the Yukon Stable Block. D.K. Norris (pers. comm., 1991) has pointed out that the Royal Mountain Platform may be allochthonous, and if it is, its relationship to surrounding rocks may be tectonic rather than depositional.

Richardson Trough

The Richardson Trough approximately coincides with the present Richardson Mountains. Its approximate extent in Devonian time was illustrated by A.W. Norris (1968b, fig. 7, p. 53), based on the distribution of the Prongs Creek Formation, which is now included in the Road River Formation. D.K. Norris (*in* D.K. Norris and Yorath, 1981, p. 82) has pointed out that the Richardson Trough, as a fault-bounded intracratonic depression, is a taphrogeosyncline in the sense of Kay (1945, p. 1172). It is also an aulacogen in the sense of Shatsky and Bogdanoff (1960), as first suggested by Churkin (1975, p. 454).

Blackstone Trough

The name Blackstone Trough was introduced by Lenz (1972, p. 328, 331, fig. 3), to apply to an area marked by basinal shale that extends west and southwest of the southwest margin of the Richardson Trough. The extent of the Blackstone Trough was first delineated by A.W. Norris (1968b, fig. 7, p. 53) in showing the distribution of the Michelle Formation.

Selwyn Trough

The name Selwyn Trough or Basin used by Gabrielse (1967, fig. 1, p. 272) is applied to an area of basinal sedimentation, part of which extends into the southwestern part of the report area. This name is more or less synonymous with the term Cordilleran Trough of Lenz (1972, fig. 3, p. 328, 332, 333). The southwestern edge of the Selwyn Trough is marked by the Tintina Trench (Gabrielse, 1967, fig. 1, p. 272).

Rapid Trough

The name Rapid Trough was introduced by A.W. Norris (1985) to apply to an area of scattered remnants of pre-Carboniferous basinal sediments in the northwestern part of the report area within the Rapid Depression of D.K. Norris (1983). These remnants are strongly suggestive of a Paleozoic trough in that area. The condensed sequence of Road River sediments on the Dave Lord High, at Section 13 on Porcupine River, points to a connection between the southern end of the Rapid Trough and the northwestern end of the Richardson Trough.

Hazen Trough

During Devonian time a northeast splay of the Richardson Trough was connected with the Hazen Trough of the Arctic Islands as indicated by trough sediments at Jurassic Butte (68°02′N, 135°39′W) (Nassichuk et al., 1978, p. 67–73), on the west side of Banks Island (Miall, 1976a, b), and in the Arctic islands to the northeast (Lenz, 1972; Miall, 1976a, b; Trettin et al., 1972).

Dave Lord High

The name Dave Lord High used here closely follows the usage by Lenz (1972). It is a long, narrow, northeast trending, arcuate area, which extends from east-central Alaska northeast to the big bend of the Porcupine River. The Dave Lord High cuts across the the Yukon Stable Block to subdivide it into northwestern and central segments. Pronounced hiatuses of varying magnitudes are evident in the Paleozoic sediments along and adjacent to this high.

Bonnet Plume High

The name Bonnet Plume High was introduced by Lenz (1972, p. 327, 328) to apply to a north–south trending area covering the Knorr Range and a southern extension into the Wernecke Mountains. Lenz (1972, p. 328) indicated that this area was emergent from Early Ordovician to early Siegenian, and from late Emsian to Givetian time. However, we know that one of the periods of emergence was not as long as indicated by Lenz because Ordovician graptolites were collected from the area at 65°28.5′N, 134°17.5′W in 1973 (GSC locality 89892; Fossil Report O-10-BSN-73). The hiatus from late Emsian to Givetian time is the more firmly established interval, based on sections near the Bonnet Plume High.

Devonian igneous intrusions

The igneous intrusions within the northwestern part of the report area (Fig. 7.5) have been described by D.K. Norris and Yorath (1981, p. 46, 47, Table 2) and D.K. Norris (1983), and in more detail by Burwash (Chapter 14). They consist of granite, quartz monzonite and syenodiorite, and occur as small isolated stocks to large batholiths. Radiometric dates for the various intrusions are as follows (D.K. Norris, 1983): Mount Fitton, 370 Ma; Mount Sedgwick, 355 Ma; Hoidahl intrusion, 406 Ma; and a small intrusion in Keele Block, 372 Ma. The spread of the radiometric ages varies from Silurian to Late Devonian. The Ellesmerian Orogeny in the area was dated by D.K. Norris (*in* D.K. Norris and Yorath, 1981, p. 46) at about 350 ± 10 Ma, which is within Late Devonian time.

PALEOGEOGRAPHY

Lochkovian, Pragian and Lower Emsian (Lower Devonian)

Open marine, carbonate (neritic) facies (Fig. 7.16) are recognized by the presence of such brachiopods as *Gypidula pelagica* (lower Lochkovian); *Spirigerina supramarginalis* and *Toquimaella kayi* (upper Lochkovian); *Cortezorthis*, *Plicocyrtina*, *Davidsoniatrypa* and other forms (Pragian); and the *Sieberella-Nymphorhynchia pseudolivonica* fauna (lower Emsian) (Lenz, 1966, 1968, 1972, 1977a, b).

In the shale (pelagic) facies (Fig. 7.16), characteristic fossils include *Monograptus uniformis* and *M. aequabilis* (lower Lochkovian); *M. hercynicus* (upper Lochkovian); and *M. telleri, M. thomasi* and *M. yukonensis* (Pragian).

In restricted marine carbonate facies, the giant ostracode, *Moelleritia canadensis*, first appears in rocks equivalent to *Sieberella-Nymphorhynchia pseudolivonica* fauna, which in turn is aligned with conodonts of the *dehiscens* Zone. The uppermost range of this distinctive ostracode is at or near the top of the Emsian Stage.

During the Lochkovian to early Emsian interval, restricted marine dolomite and dolomitic limestone were deposited on the Mackenzie Platform (Unnamed carbonate unit) and on the Yukon Stable Block and White Mountains Platform (Kutchin Formation; A.W. Norris, 1985). These rocks are generally barren of fossils except for the sporadic earliest occurrence of the ostracode, *Moelleritia canadensis*, in the more calcareous upper parts of some sequences.

The position of the Blackstone Trough during this interval was marked by the deposition of the Road River and Michelle formations, with the latter representing a transition between shale basin and carbonate platform facies. The Michelle Formation, although relatively thin, is one of the most abundantly fossiliferous in the report area. Both neritic and pelagic faunas are well represented in the formation.

The Richardson Trough extended southward as a narrow channel through the headwaters of Royal Creek to connect with the Selwyn Trough. To the north, it widened to cover the lower Porcupine River (locality 13; A.W. Norris, 1985, fig. 7). From there the trough extended westward into the Salmontrout River area of east-central Alaska (Lane and Ormiston, 1979). The connection between the Richardson Trough and Rapid Trough to the northwest is indicated by the presence of shale of the Road River Formation at several localities including the headwaters of Johnson Creek, from which *M. yukonensis* has been recovered (D.K. Norris, 1970).

Upper Emsian (Upper Lower Devonian)

Rock units included in the upper Emsian (upper Lower Devonian) interval include the following: the upper part of the "Bear Rock Formation" on the Mackenzie Platform east of the report area; the Cranswick Formation on the western part of the Mackenzie Platform; part of the Road River Formation in the southwestern part of the Richardson Trough and the northwestern part of the Rapid Trough (D.K. Norris, 1986); the lower parts of the Ogilvie Formation and Unnamed shale unit on the Yukon Stable Block; and the lower part of the Ogilvie Formation on the White Mountains Platform.

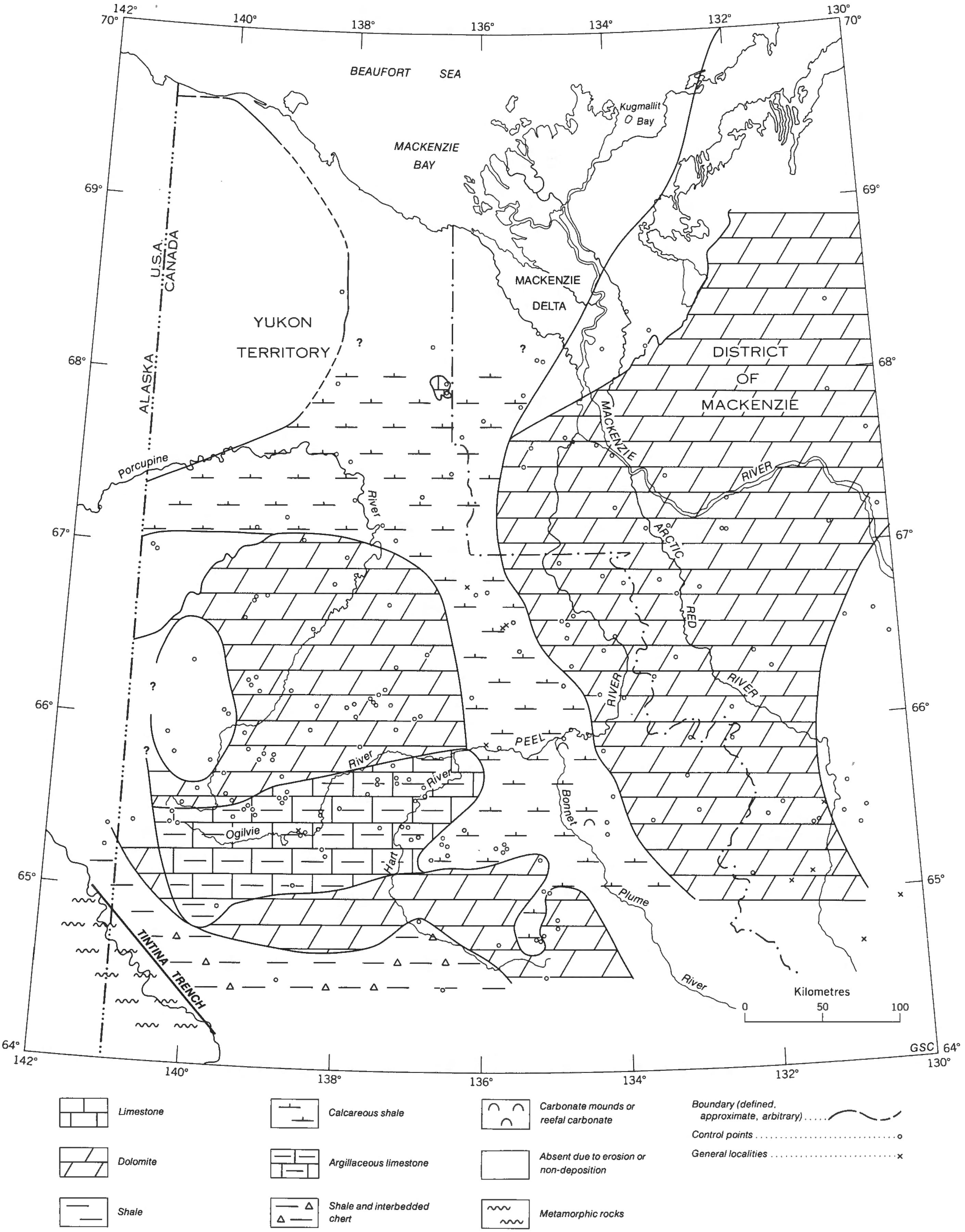

Figure 7.16. *Lochkovian, Pragian and lower Emsian (Lower Devonian) lithofacies (A.W. Norris, 1985).*

In adjacent Alaska, rock units included in this interval comprise a large part of the Limestone and shale member of the McCann Hill Chert of the Nation River area, and the upper part of the Salmontrout Formation of the Salmontrout River area.

The upper Emsian interval is indicated by conodonts of the *gronbergi*, *inversus* and *serotinus* zones and brachiopods of the *Carinatina lowtherensis* fauna. The widely distributed and distinctive echinoderm ossicle, *Gasterocoma*? *bicaula*, appears in abundance immediately above beds containing conodonts of the *dehiscens* Zone, and ranges upward into beds immediately below the conodont *costatus* Zone. In restricted marine carbonate facies, the conodont *Pandorinellina* sp. A of Uyeno and Mason (1975) is reported by Chatterton (1979) to be associated with conodonts of the *serotinus* and *costatus* zones, and is also known to overlap the upper range of the large ostracode, *Moelleritia canadensis*.

Evidence from various sections suggest that the Bonnet Plume High and the adjacent southern part of the Richardson Trough were emergent for at least part of this interval (Fig. 7.17). In this area, an unconformity undoubtedly separates the top of the Road River Formation from the base of the Canol Formation at six or more localities. These have been documented by Bassett and Stout (1968, p. 744), Lenz (1972, p. 347), Perry et al. (1974), Uyeno and Mason (1975), and A.W. Norris (1968b, 1985).

During the upper Emsian interval, the southwestern part of the Richardson Trough formed a broad connection with the Selwyn Basin to the southwest (Fig. 7.17). At this time, the Selwyn Basin also extended into the Nation River area of east-central Alaska.

Eifelian (lower Middle Devonian)

Rock units of the Eifelian interval include: the Hume Formation on the eastern and central parts of the Mackenzie Platform; the upper part of the Cranswick Formation in the Campbell Uplift segment of the Mackenzie Platform; the Road River Tongue and Mount Baird Formation in a narrow transitional belt between the Mackenzie Platform and the southeastern edge of the Richardson Trough; part of the Road River Formation in the Richardson Trough; and parts of the Ogilvie Formation and Unnamed shale unit on the Yukon Stable Block. In adjacent Alaska, rock units of this interval include the upper part of the Limestone and shale member of the McCann Hill Chert in the Nation River area, and the Old Camp Formation in the Salmontrout River area.

Rocks of Eifelian age are recognized by conodonts of the upper *patulus*, *costatus*, *australis*, *kockelianus*, and lower *ensensis* zones. Within the Hume Formation are two main broad megafaunal associations: a lower *Eoschuchertella adoceta* Zone which is commonly associated with conodonts of the *australis* Zone; and an upper *Carinatrypa dysmorphostrota* Zone associated with conodonts of the *kockelianus* Zone (Fig. 7.2).

During the Eifelian interval, dark shale and chert of the Unnamed shale unit were deposited over a large area of the Yukon Stable Block (Fig. 7.18) and overlapped the highly diachronous top of the Ogilvie Formation carbonates.

Pugh (1983, fig. 27a) recorded reef-like carbonate of presumed Eifelian age at the top of the Ogilvie Formation in the subsurface of the Chevron North Parkin Y.T. D-61 well (56°20′12″N, 137°13′01″W). This reef occurs near the eastern margin of the Yukon Stable Block and may have developed during a time when part of the adjacent Richardson Trough was emergent.

Givetian (upper Middle Devonian)

Rocks of Givetian age (Fig. 7.19) on the Mackenzie Platform within the lower Mackenzie Valley area are recognized by the following megafaunas, in ascending order: *Leiorhynchus castanea*, *Ectorensselandia laevis*, *Stringocephalus aleskanus*, *Leiorhynchus hippocastanea*, and *Grypophyllum mackenziense* zones (Pedder, 1975). Elements of these zones occur in the Hare Indian Formation (Tassonyi, 1969; Pedder, 1975); in an unnamed sandstone unit in the Grandview Hills area referred to as Map unit 4 by Cook and Aitken (1975), and described by MacKenzie, Pedder and Uyeno (1975) and Uyeno (1978); and in the bedded platformal and reefal parts of the Ramparts Formation (Tassonyi, 1969; Pedder, 1975).

Traced westward on the Mackenzie Platform from the Norman Wells-Fort Good Hope area, rocks of the lowermost Hare Indian Formation, which contain fossils of the *castanea* Zone, are last seen at Section 1 near Arctic Red River immediately east of the report area (A.W. Norris, 1985, fig. 4). The apparent absence of rocks of Givetian age on the western part of the Mackenzie Platform and throughout most of the Richardson Trough suggests that this area was uplifted and truncated by erosion prior to depositon of the Canol Formation.

On the Yukon Stable Block, the carbonate Ogilvie Formation was almost completely overlapped by dark shale, siliceous shale and dark interbedded chert of the

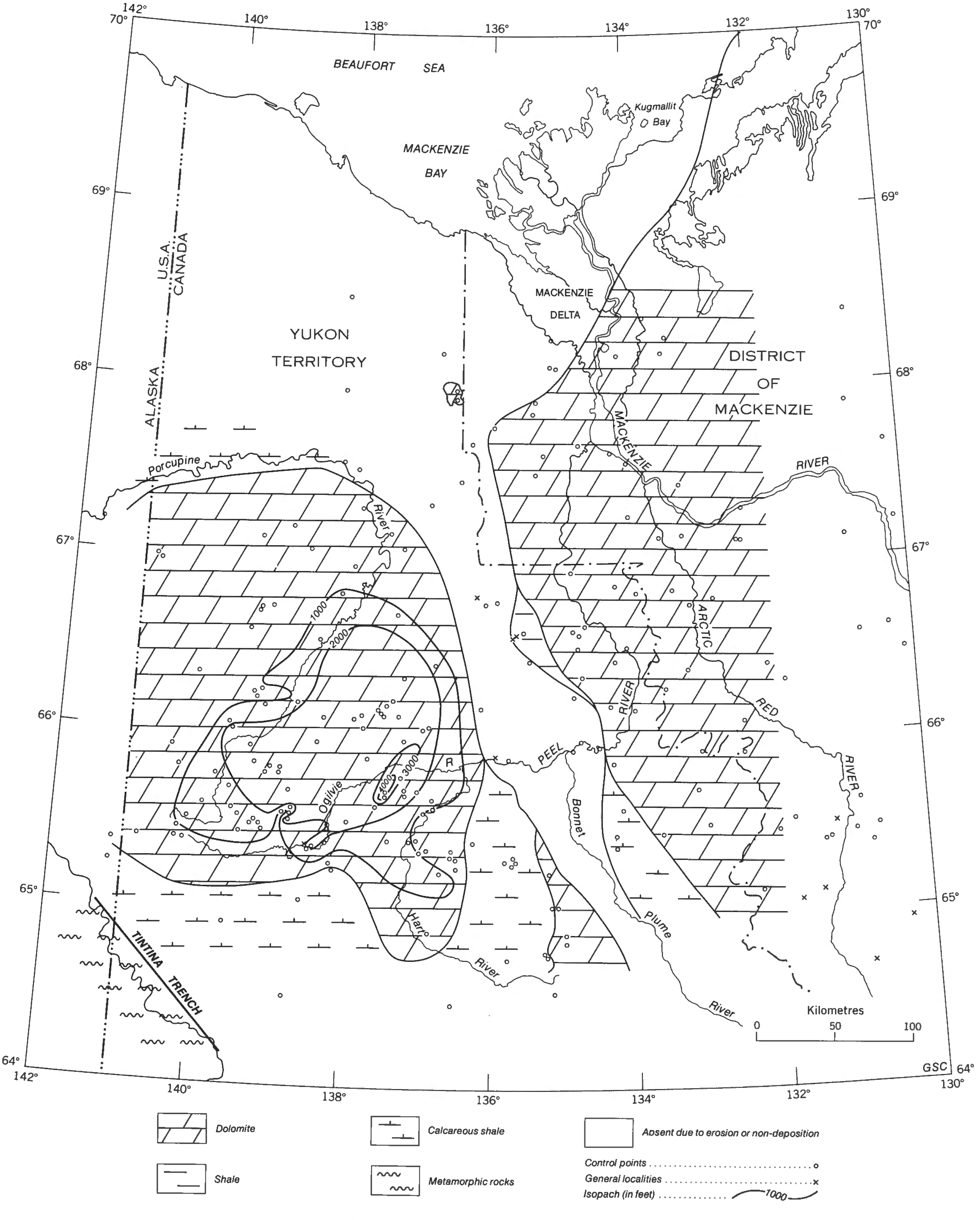

Figure 7.17. *Upper Emsian (upper Lower Devonian) lithofacies (A.W. Norris, 1985).*

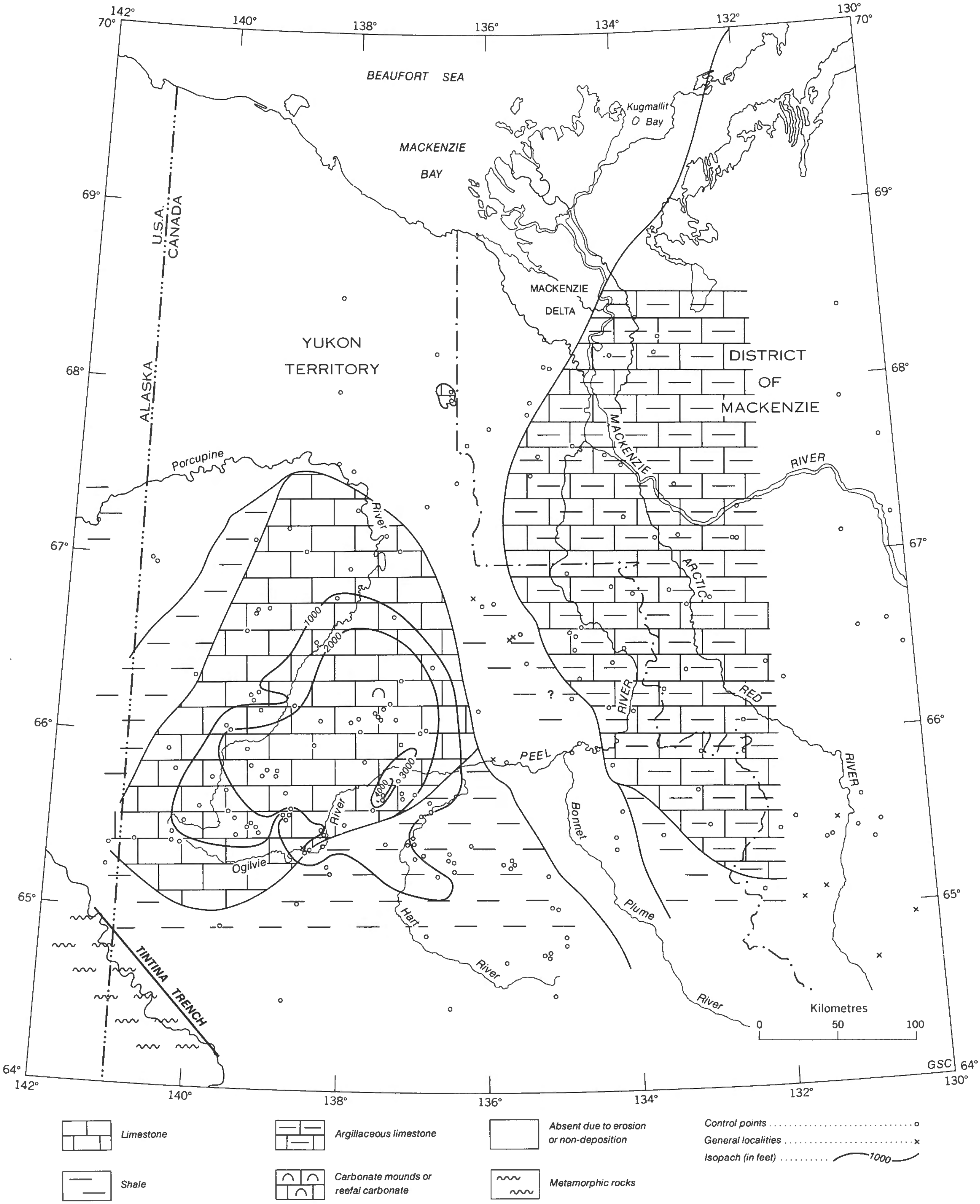

Figure 7.18. *Eifelian (lower Middle Devonian) lithofacies (A.W. Norris, 1985).*

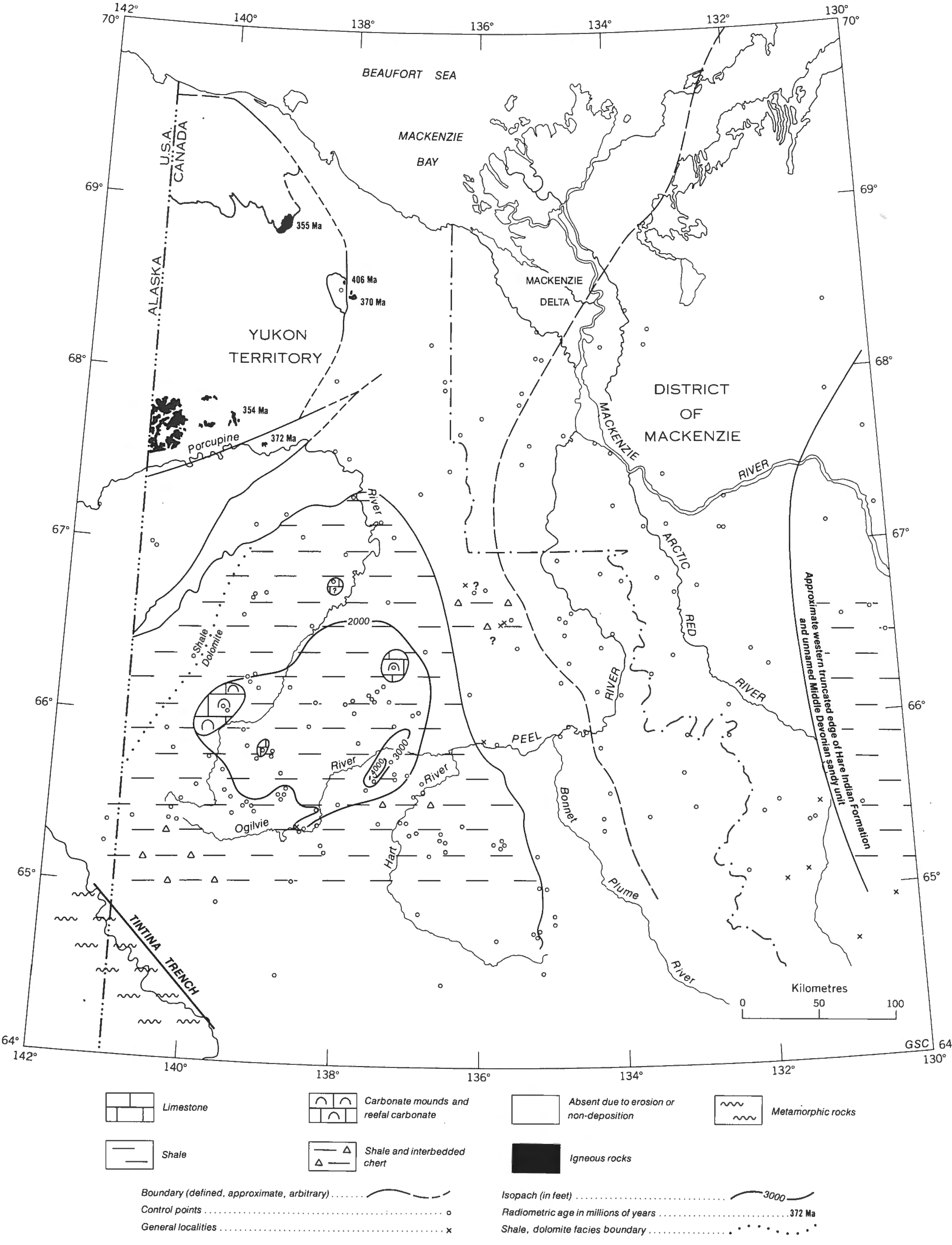

Figure 7.19. *Givetian (upper Middle Devonian) lithofacies (A.W. Norris, 1985).*

Unnamed shale unit. One of the few exceptions is in the Mount Burgess area where the upper 311 m of the Ogilvie Formation is positively dated as Givetian based on the presence of stringocephalids (A.W. Norris, 1968b, 1985). In this local area, succeeding beds of the Unnamed shale unit are missing or exceedingly thin.

In the subsurface of the Yukon Stable Block, the base of rocks equivalent to the Canol Formation can be identified in the Socony North Cathedral Y.T. B-62 well (66°11′14″N, 138°41′33″W) at 413.9 m depth, and the top of the Ogilvie Formation at 811.1 m depth. The appearance of siltstone and sandstone in the Unnamed shale unit indicates that coarse clastic sedimentation started in Middle Devonian time in this western part of the report area, and marks the beginning of the uplift and the onset of the Ellesmerian Orogeny to the north.

Uppermost Givetian (uppermost Middle Devonian), Frasnian and Famennian (Upper Devonian)

Rock units of this interval in the report area include the Canol, Imperial and lower part of the Tuttle formations. However, for convenience of illustration, only rocks of the Canol and Imperial formation are included in Figure 7.20; data pertaining to the Tuttle Formation are presented in Figure 7.21. The base of the conodont Lower *asymmetrica* Zone has been selected by the Subcommission on Devonian Stratigraphy to mark the base of the Upper Devonian internationally (Ziegler and Klapper, 1985). This means that the base of the Upper Devonian in the report area occurs at or near the base of the Canol Formation. Faunal evidence suggests that the Canol Formation is aligned mainly with the Lower *asymmetrica* conodont zone and in part with the lowermost *asymmetrica* Zone (Braun et al., 1989).

The relatively thin, black, fissile, bituminous, and in places siliceous shale of the Canol Formation is widely distributed on the Mackenzie Platform. Numerous workers have documented an unconformity at the base of the Canol Formation with the hiatus increasing in a westerly direction up to the southwest end of the Richardson Trough, beyond which the hiatus has not been demonstrated.

On the Yukon Stable Block, beds equivalent to the Canol Formation have been recognized at only one locality, the Socony North Cathedral Y.T. B-62 well (66°11′14″N, 138°41′53″W) between depths of 381 and 413.9 m. The beds contain spathiocarids or anaptychi identical to those recovered from the formation east of the Richarson Trough. At this locality the Canol-equivalent is included in the upper part of the Unnamed shale unit.

The sediments and sedimentary pattern of the succeeding Frasnian to Famennian Imperial Formation are considerably different from all older Devonian rock units. The Imperial Formation in the southeastern part of the area consists of fine grained clastics, predominantly shale and siltstone, with some fine grained sandstone and minor limestone beds in the upper part. A similar sequence, lacking the limestone beds, can be traced westward to Section 1 near Arctic Red River. The lower and upper parts of the Imperial Formation at this section are of marine turbidite and shallow marine origin, respectively (Hills and Braman, 1978). In contrast, all of the Imperial sequence at Section 35 on Trail River is considered to be of turbidite origin. On the west side of the Richardson Anticlinorium, the Imperial Formation consists of relatively coarse grained greywacke and flysch-like siltstone and shale in places containing fragmentary plants. Marine megafossils have been recovered from only one locality, at Section 1 in the Arctic Red River area. Spores have been recovered from throughout the Imperial Formation east of the Richardson Anticlinorium, but those from west of the anticlinorium are generally so highly carbonized that they cannot be identified.

In adjacent east-central Alaska, the Nation River Formation has a similar lithology and stratigraphic position to the Imperial Formation of the report area.

South of the report area in the Selwyn Trough, clastic rocks equivalent to the Imperial Formation are included in the Earn Group described by Gordey et al. (1987), Gordey (1989), and others.

Uppermost Famennian (Upper Devonian) and Lower Carboniferous

The coarse clastic unit named the Tuttle Formation by Pugh (1983) occurs typically in the areas flanking the Richardson Anticlinorium (Fig. 7.21). The formation ranges in age from late Famennian (late Late Devonian) to early Carboniferous, based on palynomorphs dated by D. C. McGregor (*in* A.W. Norris, 1985) and Braman (1981).

Along the east flank of the Richardson Anticlinorium the grade size decreases from coarse conglomerate in the north to fine grained sandstone and siltstone in the south. Along the west flank of the anticlinorium the rocks of the Tuttle Formation are

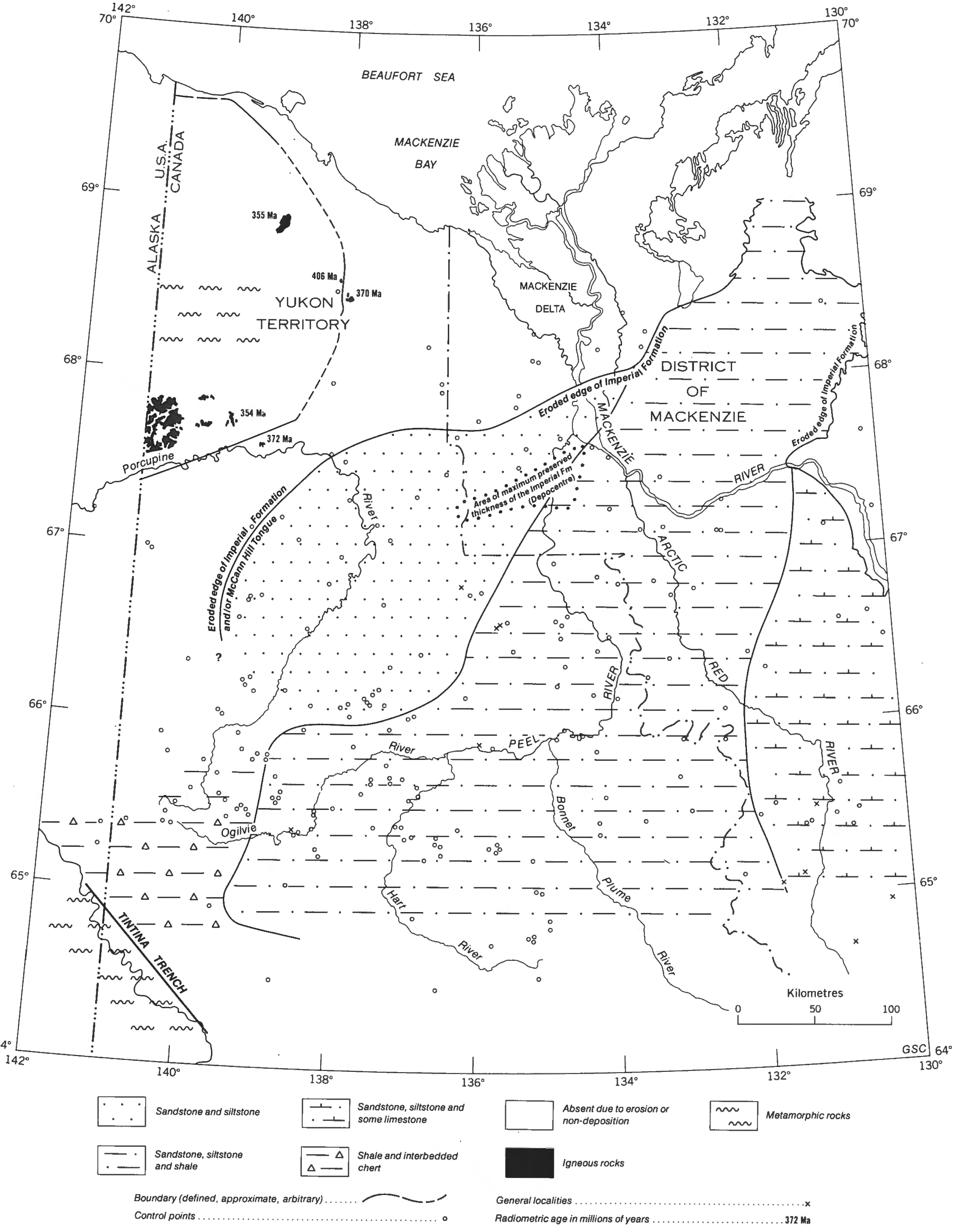

Figure 7.20. *Uppermost Givetian (uppermost Middle Devonian), Frasnian and Famennian (Upper Devonian) lithofacies (A.W. Norris, 1985).*

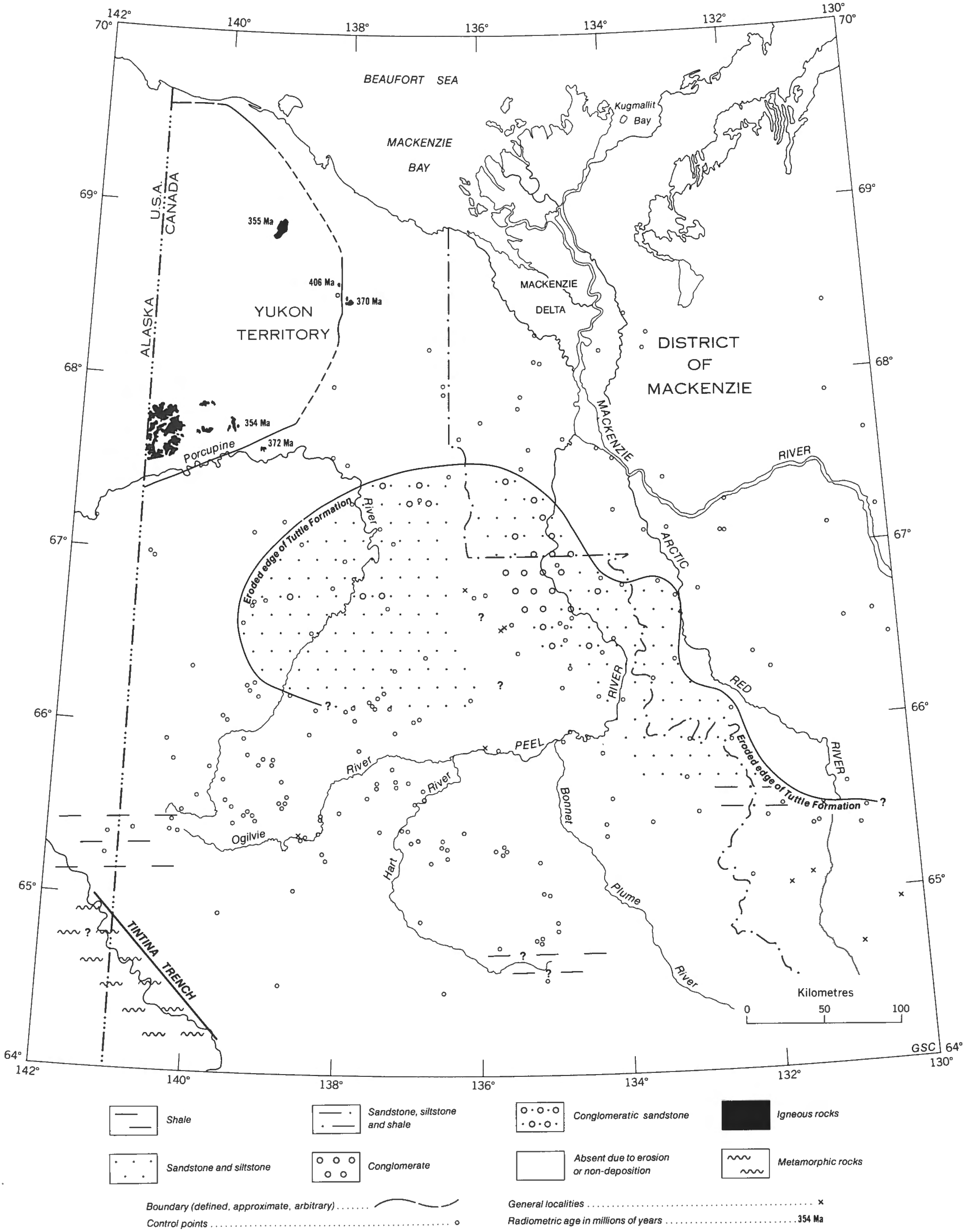

Figure 7.21. *Uppermost Upper Devonian and Lower Carboniferous lithofacies (A.W. Norris, 1985).*

referred to by Pugh (1983) as conglomeratic greywacke which grade southward into the Ford Lake Shale.

Hills and Braman (1978, p. 36) interpreted the rocks of the Tuttle Formation to be of turbidite origin. Sedimentary features such as load casts, flutes and tool marks indicate transport to the south from a source area in the north. In contrast, Lutchman (1977) interpreted the sediments of the Tuttle Formation as a southward advancing Mississippian clastic wedge of fluvio-deltaic origin.

Embry and Klovan (1976, p. 602) have suggested that the Imperial (Devonian) and Tuttle (Devonian to Mississippian) formations of the report area are the southwestern extension of the Arctic Islands clastic wedge.

At two sections at the north end of the Richardson Anticlinorium (Sections 33 and 34; A.W. Norris, 1985, fig. 8), an angular unconformity separates the Imperial Formation from the Permian (A.W. Norris, 1986b, Pl. 11, p. 282), and in places, as near Sheep Creek (67°40′N, 136°15′W), the Imperial beds have been tightly folded (A.W. Norris, 1968b, p. 9, p. 280). This deformation coincided with the intense phase of the Ellesmerian Orogeny of the Arctic Archipelago (Thorsteinsson and Tozer, 1960), probably during latest Devonian to earliest Mississippian (D.K. Norris, 1974, p. 30; Norris and Dyke, 1987, p. 178).

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CHAPTER 8

UPPER DEVONIAN TO PERMIAN

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Abstract

The Upper Devonian and Carboniferous comprise a southern and a northern succession separated by the Ancestral Aklavik Arch. The southern succession, deposited in the Mackenzie Basin and the Prophet Trough, consists of Frasnian to Gzhelian strata. The northern succession comprises Viséan to Moscovian strata that onlapped the Yukon Fold Belt from the Prophet Trough. Both packages comprise marine to continental siliciclastics overlain by basinal to supratidal platform and ramp carbonates.

The northeast-trending Late Devonian Mackenzie Basin and its Carboniferous successor, the Prophet Trough, developed in the foreland of a continental margin volcanic/plutonic belt and bifurcated in the north at the Yukon Fold Belt. During the Late Devonian and Tournaisian, the compressional northeast arm of the Mackenzie Basin/Prophet Trough lay southeastward of the Yukon Fold Belt, which resulted from a predominantly Late Devonian orogeny. Post-Tournaisian subsidence in the Prophet Trough resulted from extension.

The Permian (Asselian to Wordian) overlies a latest Carboniferous to Early Permian unconformity. It comprises basinal to peritidal siliciclastics, carbonates, and chert that onlapped the Ancestral Aklavik Arch from the Ishbel Trough and were deposited in an unnamed basin to the north. The extensional Ishbel Trough succeeded the Prophet Trough and extended northward to the northeast-trending latest Carboniferous and Permian Ancestral Aklavik Arch of block-faulted origin, which developed across the southern Yukon Fold Belt.

Frasnian to earliest Tournaisian climates were tropical; those of the Late Permian were temperate, thereby, indicating a northward shift of the region.

Résumé

Le Dévonien supérieur et le Carbonifère comprennent une succession méridionale et une succession septentrionale séparées par la protoarche d'Aklavik. La succession méridionale, déposée dans le bassin de Mackenzie et la cuvette de Prophet, comprend des couches frasniennes à gzhéliennes. La succession septentrionale comprend des couches viséennes à moscoviennes qui ont chevauché la zone de plissement du Yukon à partir de la cuvette de Prophet. Les deux ensembles contiennent des roches silicoclastiques marines à continentales recouvertes de roches carbonatées de bassin et de plate-forme et rampe supratidales.

Le bassin de Mackenzie du Dévonien tardif à direction nord-est et son successeur du Carbonifère, la cuvette de Prophet, se sont formés dans l'avant-pays d'une ceinture volcanique ou plutonique de marge continentale et ont bifurqué dans le nord à la zone de plissement du Yukon. Durant le Dévonien tardif et le Tournaisien, le bras de compression nord-est du bassin de Mackenzie et de la cuvette de Prophet se trouvait au sud-est de la zone de plissement du Yukon, qui a été formée au cours d'une orogenèse datant principalement du Dévonien tardif. La subsidence post-tournaisienne dans la cuvette de Prophet est le résultat d'une extension.

Le Permien (de l'Asselien au Wordien) repose sur une discordance du Carbonifère terminal au Permien précoce. Il comprend des roches silicoclastiques, des roches carbonatées et des cherts de milieu de bassin à milieu péritidal qui ont chevauché la protoarche d'Aklavik à partir de la cuvette d'Ishbel et se sont déposés dans un bassin non désigné au nord. La cuvette d'Ishbel, cuvette d'expansion, a succédé à la cuvette de Prophet et s'est prolongée vers le nord jusqu'à la protoarche d'Aklavik à direction nord-est du Carbonifère terminal et du Permien crée par morcellement par failles à travers le sud de la zone de plissement du Yukon.

Les climats du Frasnien au Tournaisien initial étaient tropicaux; ceux du Permien tardif étaient tempérés, indiquant, par conséquent, un déplacement vers le nord de la région.

INTRODUCTION

The focus of this chapter is the Carboniferous and Permian succession and tectonic elements of northern Yukon and northwestern District of Mackenzie (Fig. 8.1). Tectonism and sedimentation of the Late Devonian profoundly influenced that of the Carboniferous and Permian. Consequently, the Late Devonian tectonic history and the Upper Devonian strata of the Endicott Group, which spans the Carboniferous/Devonian boundary, are considered briefly as well. The Upper Devonian strata, also discussed by A.W. Norris (Chapter 7), lie mainly in the south and northeast (Figs. 8.1, 8.2). Carboniferous and Permian rocks of the study area are most completely preserved in the Ogilvie Mountains (Eagle Plain area), the northern Richardson Mountains and the British Mountains (Figs. 8.1–8.3). Pronounced truncation beneath several regional unconformities has removed much of the upper Paleozoic from intervening areas, where erosional remnants of the succession are commonly preserved in grabens resulting from Permian and Mesozoic block faulting.

The Yukon/District of Mackenzie succession, continuous with that of northeast and east-central Alaska (Figs. 8.2, 8.4), consists of shallow-shelf to basinal-marine carbonates and siliciclastics, with subordinate coal-bearing, nonmarine deposits to the north and east. Most of the Carboniferous was deposited in northern Prophet Trough (Richards, 1989; Richards, et al., 1993), which succeeded several Late Devonian elements including the Richardson Trough and northern Mackenzie Basin (Morrow and Geldsetzer, 1988; Pugh, 1983, p. 50–51; Chapter 7). Permian strata were deposited mainly in the Ishbel Trough (Henderson, 1989; Henderson, et al., 1993), which formed in approximately the same region as the former Prophet Trough. The Carboniferous deposits onlapped the Ellesmerian Yukon Fold Belt, whereas the Permian onlapped the latest Carboniferous to Permian Ancestral Aklavik Arch (Figs. 8.5, 8.6). As in more southerly parts of the eastern Canadian Cordillera, a regional, sub-Permian disconformity is present throughout most of the study area (Fig. 8.3). In contrast to southwestern Canada, however, a thick, relatively complete Upper Carboniferous succession is preserved beneath this disconformity in northern Yukon. Upper Paleozoic deposits and biostratigraphic sequences in the study area are closely similar to those in northern and east-central Alaska, indicating a common depositional and tectonic history for the two areas during the Late Devonian and late Paleozoic.

Most of the chapter is based on the re-evaluation of samples and data collected by E.W. Bamber during the 1960s (Bamber and Waterhouse, 1971). It also incorporates information acquired by the re-examination of several key sections and exposures during the late 1980s.

Previous work

Formal stratigraphic nomenclature for most of the Upper Paleozoic of the study area was established by Bamber and Waterhouse (1971), who described the lithostratigraphy, depositional history, and biostratigraphy of the Carboniferous and Permian succession. The reader is referred to their paper for a summary of pertinent literature published prior to 1971. Detailed descriptions of outcrop stratigraphic sections used in the study by Bamber and Waterhouse (1971) were subsequently published by Bamber (1972).

In a description of the Upper Paleozoic subsurface stratigraphy of Eagle Plain, Martin (1972) illustrated surface-subsurface relationships, discussed the petroleum potential of the area, and recognized several new stratigraphic units in the Viséan to lower Serpukhovian Hart River Formation. This work was revised by Graham (1973), who abandoned Martin's three-fold division of the Hart River Formation.

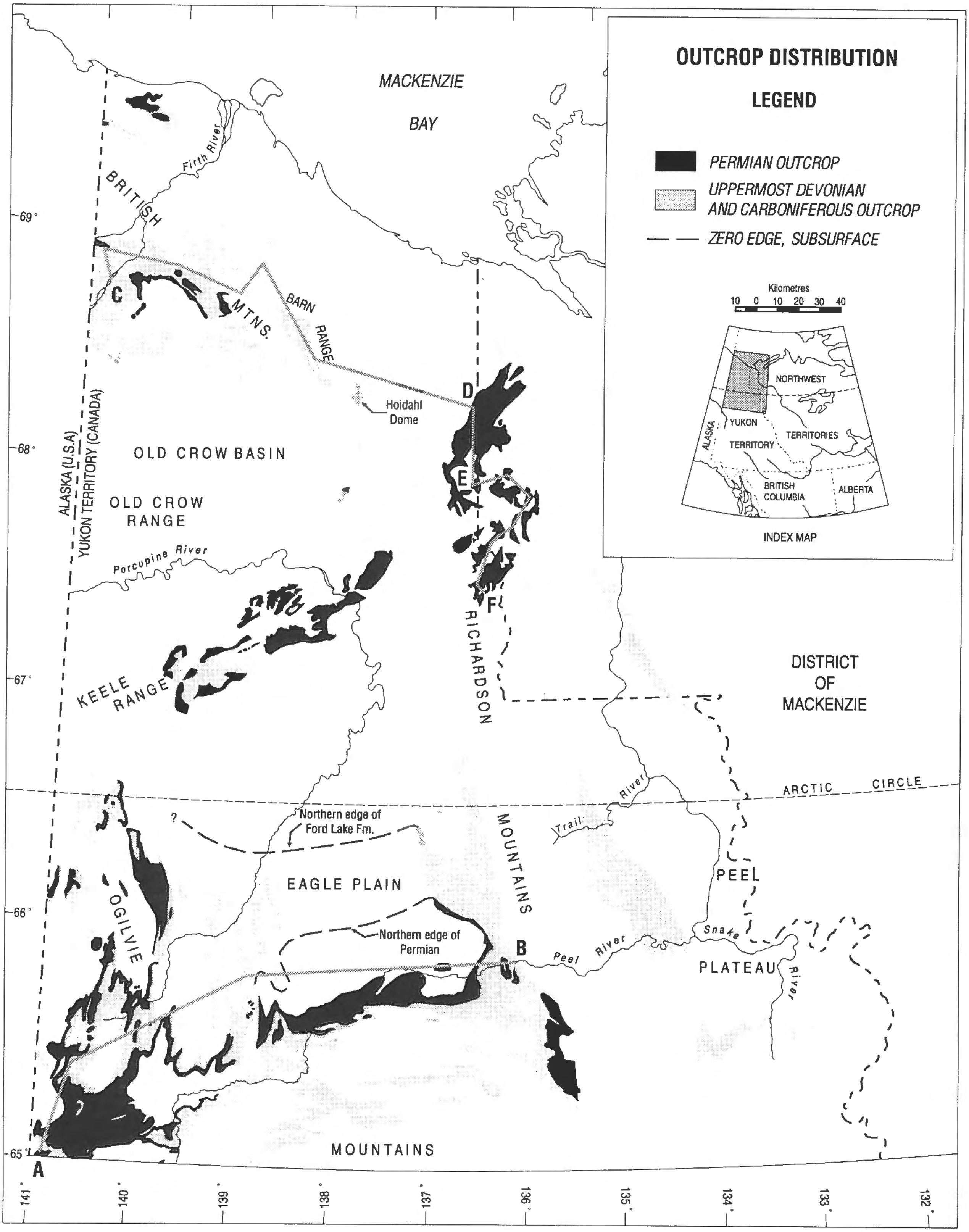
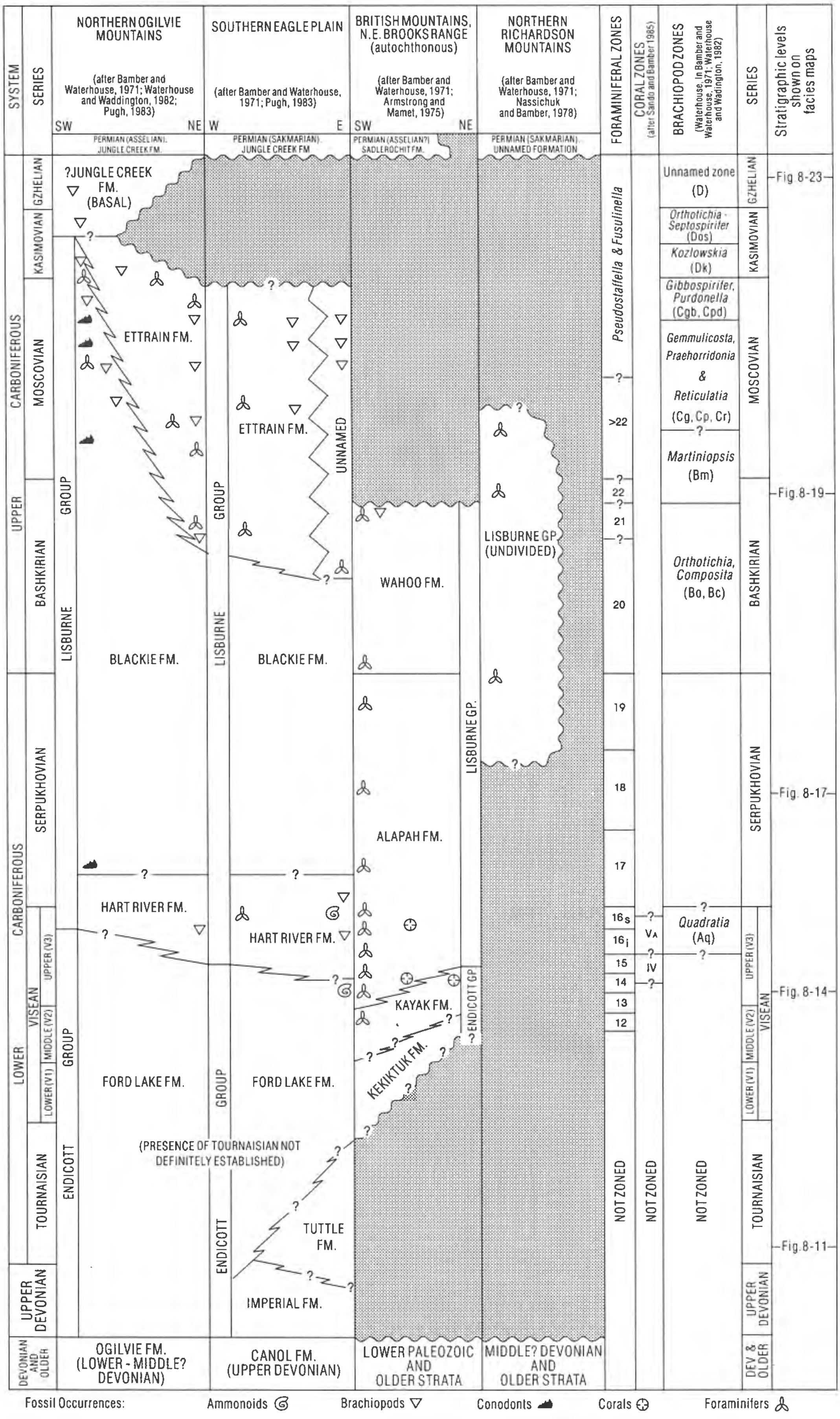


Figure 8.1. *Map showing locations of cross-sections [Figs. 8.8 (A–B), 8.9 (C–D–E), 8.31 (D–E–F), 8.35 (A–B)] and distribution of Carboniferous and Permian deposits (after D.K. Norris, 1985; Hamblin, 1990). Upper Carboniferous deposits are preserved locally in the northern Richardson Mountains at D and E.*


SYSTEM
SERIES
NORTHERN OGILVIE MOUNTAINS
(after Bamber and Waterhouse, 1971; Waterhouse and Waddington, 1982; Pugh, 1983)
SW
NE
SOUTHERN EAGLE PLAIN
(after Bamber and Waterhouse, 1971; Pugh, 1983)
W
E
BRITISH MOUNTAINS, N.E. BROOKS RANGE (autochthonous)
(after Bamber and Waterhouse, 1971; Armstrong and Mamet, 1975)
SW
NE
NORTHERN RICHARDSON MOUNTAINS
(after Bamber and Waterhouse, 1971; Nassichuk and Bamber, 1978)
FORAMINIFERAL ZONES
CORAL ZONES (after Sando and Bamber 1985)
BRACHIOPOD ZONES (Waterhouse, in Bamber and Waterhouse, 1971; Waterhouse and Waddington, 1982)
SERIES
Stratigraphic levels shown on facies maps
PERMIAN (ASSELIAN) JUNGLE CREEK FM.
PERMIAN (SAKMARIAN) JUNGLE CREEK FM
PERMIAN (ASSELIAN?) SADLEROCHIT FM.
PERMIAN (SAKMARIAN) UNNAMED FORMATION
UPPER CARBONIFEROUS
LOWER CARBONIFEROUS
GZHELIAN
KASIMOVIAN
MOSCOVIAN
BASHKIRIAN
SERPUKHOVIAN
VISEAN
UPPER (V3)
MIDDLE (V2)
LOWER (V1)
TOURNAISIAN
UPPER DEVONIAN
DEVONIAN AND OLDER
?JUNGLE CREEK FM. (BASAL)
ETTRAIN FM.
LISBURNE GROUP
BLACKIE FM.
HART RIVER FM.
ENDICOTT GROUP
FORD LAKE FM.
ETTRAIN FM.
UNNAMED
LISBURNE GROUP
BLACKIE FM.
HART RIVER FM.
FORD LAKE FM.
(PRESENCE OF TOURNAISIAN NOT DEFINITELY ESTABLISHED)
ENDICOTT GROUP
TUTTLE FM.
IMPERIAL FM.
WAHOO FM.
ALAPAH FM.
LISBURNE GP.
KAYAK FM.
KEKIKTUK FM.
ENDICOTT GP.
LISBURNE GP. (UNDIVIDED)
OGILVIE FM. (LOWER - MIDDLE? DEVONIAN)
CANOL FM. (UPPER DEVONIAN)
LOWER PALEOZOIC AND OLDER STRATA
MIDDLE? DEVONIAN AND OLDER STRATA
Pseudostaffella & Fusulinella
>22
22
21
20
19
18
17
16s
16i
15
14
13
12
NOT ZONED
VA
IV
NOT ZONED
Unnamed zone (D)
Orthotichia - Septospirifer (Dos)
Kozlowskia (Dk)
Gibbospirifer, Purdonella (Cgb, Cpd)
Gemmulicosta, Praehorridonia & Reticulatia (Cg, Cp, Cr)
Martiniopsis (Bm)
Orthotichia, Composita (Bo, Bc)
Quadratia (Aq)
NOT ZONED
GZHELIAN
KASIMOVIAN
MOSCOVIAN
BASHKIRIAN
SERPUKHOVIAN
VISEAN
UPPER (V3)
MIDDLE (V2)
LOWER (V1)
TOURNAISIAN
UPPER DEVONIAN
DEV & OLDER
Fig 8-23
Fig. 8-19
Fig. 8-17
Fig. 8-14
Fig. 8-11
?
Fossil Occurrences:
Ammonoids
Brachiopods ▽
Conodonts
Corals
Foraminifers

Graham presented new seismic data and additional age determinations in support of an alternative interpretation of the stratigraphic and facies relationships, distribution, and depositional significance of subsurface and surface Carboniferous and Permian units.

As part of a comprehensive study of the Paleozoic rocks in the Peel River map area, Pugh (1983) presented regional cross-sections demonstrating relationships between Upper Paleozoic units in the Eagle Plain area and correlatives on the flanks of the Richardson Mountains to the east and in the Ogilvie Mountains to the south. He introduced new nomenclature for widespread Upper Devonian and Carboniferous, basinal, shelf, slope, and coarse grained terrigenous deposits.

The lithostratigraphy, depositonal and tectonic history, and biostratigraphy of the Carboniferous and Permian of the study area were included in several regional geological summaries of the eastern Canadian Cordillera and Interior Plains (Bamber et al., 1984; Richards et al., 1993; Henderson et al., 1993; Bamber et al., 1992).

D.K. Norris et al. (1963) sketched the outcrop distribution of the undivided Carboniferous and Permian on a 1:1 000 000 scale regional compilation map. The outcrop distribution of the Carboniferous and Permian formations has been mapped at a scale of 1:250 000 on 13 maps as part of Operation Porcupine by D.K Norris (1981a–i; 1982a–d). These maps form the basis for a 1:500 000 scale compilation published by D.K. Norris (1985). Pugh (1983) provided subsurface isopach and lithofacies maps of upper Paleozoic formations in the Peel River (Eagle Plain) map area.

Figure 8.2. *Correlation of Carboniferous lithostratigraphic units in northern Yukon Territory and northwestern District of Mackenzie with standard chronostratigraphic units and Carboniferous zonal schemes. The figure also shows established occurrences of biozones in Canada and stratigraphic levels of lithofacies maps (Figs. 8.11, 8.14, 8.17, 8.19, 8.23). The foraminiferal zones are from Mamet and Skipp (1970) and Mamet and Ross (in Bamber and Waterhouse, 1971). Question marks indicate that the position of the lines is uncertain (after Bamber et al., 1989, fig. 2; Richards et al., 1993, fig. 4E.3).*

Various paleotectonic reconstructions have been proposed for the study area and adjacent areas in Alaska and the Northwest Territories (Churkin, 1973; Tailleur, 1973; Nilsen, 1981; Ziegler, 1988; Embry, 1988), but all of these models have serious problems as discussed by Nilsen (1981, p. 207–214). Upper Paleozoic tectonic elements in the study area were briefly discussed by D.K. Norris (1973), Bell (1973), Richards et al. (1993), and Henderson et al. (1993). Upper Paleozoic tectonic and depositional histories of the area were briefly outlined by Brosgé and Dutro (1973), Bamber and Waterhouse (1971), Bell (1973), Richards et al. (1993), and Henderson et al. (1993).

In a recent paper on the Carboniferous and Permian biostratigraphy of the area, Bamber et al. (1989) presented regional and international correlations of the succession and summarized all available published and current distribution data on brachiopods, foraminifers, conodonts, palynomorphs, corals and ammonoids. They also compared these groups with correlative faunas and floras from North America and Eurasia. Most of their biostratigraphic data and correlations are incorporated in this paper (Figs. 8.2, 8.3). New palynological data (Utting et al., 1989; Utting, 1991) indicate a late Tournaisian to early Viséan age for the uppermost Kekituk and lowest Kayak formations and an early to late Viséan age for the overlying Kayak Formation. These new data also demonstrate that the Hart River Formation is of late Viséan to Serpukhovian age at its stratotype.

Geologic framework

In most of the study area and in northernmost Alaska, the Upper Devonian to Upper Permian is preserved as an autochthonous to parautochthonous succession deposited on the Arctic Alaska Plate and on Ancestral North America. The autochthonous deposits occur mainly in the Eagle Plain and on the flanks of the southern Richardson Mountains. Elsewhere, including the southern Brooks Range of Alaska and the Ogilvie Mountains of the Yukon Territory, the succession is largely parautochthonous. Its Holocene distribution resulted largely from Mesozoic thrusting and folding. The Brooks Range thrust belt is currently thought to have formed from southwestward-directed underthrusting of the Arctic Alaska Plate in response to its counter-clockwise rotation during the opening of the Canada Basin by rifting. The combined displacement recorded by the numerous thrust faults in the Brooks Range is in the hundreds of kilometres (Mayfield et al., 1988).

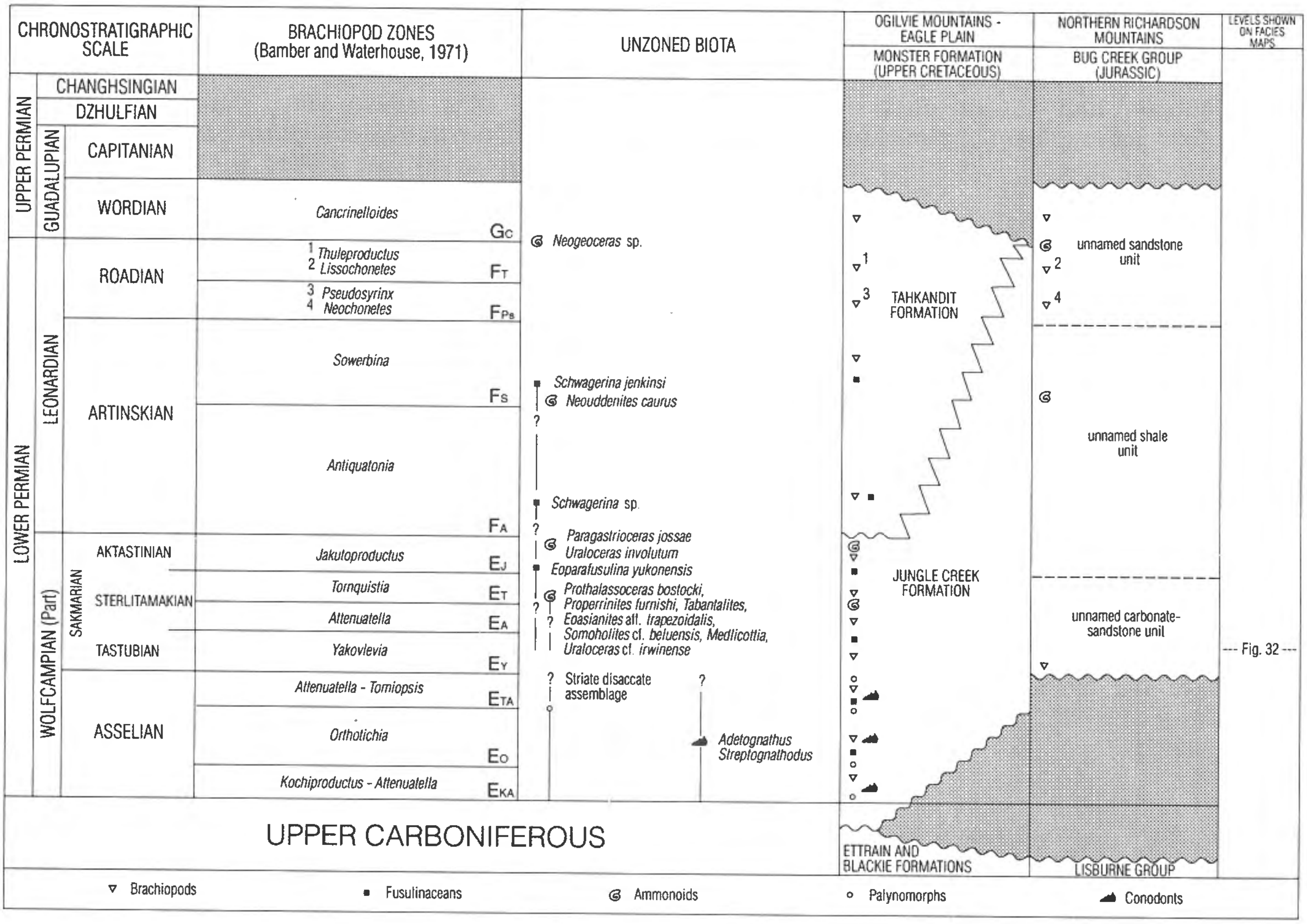


Figure 8.3. *Permian correlations and biostratigraphy, northern Yukon Territory and northwestern District of Mackenzie (after Henderson et al., 1993; Bamber et al., 1989, fig. 3). The figure also shows stratigraphic levels of the lithofacies map (Fig. 8.32).*

Paleotectonic elements and paleogeography

Upper Paleozoic tectonic elements of the study area are poorly known and only five elements have been differentiated (Figs. 8.5, 8.6): Yukon Fold Belt, Prophet Trough, Ishbel Trough, Ancestral Aklavik Arch, and the cratonic platform. In contrast, numerous Devonian elements have been recognized (A.W. Norris, 1985, p. 38–41; Morrow and Geldsetzer, 1988; Pugh, 1983, p. 50–51).

Yukon Fold Belt

The Yukon Fold Belt (Bell, 1973) of northern Yukon and Alaska (Figs. 8.5, 8.6) is an orogenic belt resulting from the Frasnian to Tournaisian Ellesmerian Orogeny. The west-trending Yukon Fold Belt, equivalent to the Barrovia of Tailleur (1973, p. 529) and the Borovian Highland (Morrow and Geldsetzer, 1988, p. 118, fig. 16), includes mildly to highly deformed and metamorphosed Precambrian and lower to middle Paleozoic volcanics and sedimentary rocks intruded by several Late Devonian to earliest Carboniferous plutons. Topographically high and widely exposed to deep erosion during the Late Devonian and earliest Carboniferous, the fold belt was subsequently onlapped toward the present-day north by a moderately thick succession of Carboniferous, continental to shallow-marine siliciclastic and carbonate rocks.

The mid-Paleozoic plutons in the Yukon Fold Belt of northern Yukon (Fig. 8.7) range from highly altered biotite and hornblende granite and quartz monzonite to syenodiorite which occur as isolated stocks or cupolas exposed over a few square kilometres, or batholiths covering hundreds of square kilometres (Norris and Yorath, 1981; D.K. Norris, 1985; Chapter 14). Frasnian to early Viséan ages have been calculated for the Mount Sedgewick (355 Ma), Mount Fitton (370 Ma), and Old Crow (345 Ma) batholiths and the small intrusion in the Keele block (372 Ma) (D.K. Norris, 1983; Dillon et al., 1980). These radiometric ages, based on K-Ar, U-Pb and Pb-Pb, indicate the youngest possible age of each intrusion. Recent fieldwork indicates that at least one of the plutons, the Mount Sedgewick batholith, is unconformably overlain by Viséan deposits of the Endicott Group, which include clasts derived from the pluton.

Late Devonian to earliest Carboniferous plutons resembling those in the Yukon Territory are widely distributed in the southern Brooks Range of Alaska, where a west-trending, 300 km chain of metamorphosed plutons (biotite quartz monzonite and biotite granite orthogneiss) are preserved (Fig. 8.7). The plutons are mainly Late Devonian (365 ± 15 Ma) and associated with partly coeval volcaniclastics that have bulk chemistries similar to those of the metaplutonic rocks (Dillon et al., 1980). They intrude metasedimentary basement rocks and overlying marble correlative with the Silurian to Upper Devonian Skajit Limestone. Some of the Alaskan plutons are unconformably overlain by Lower Carboniferous terrigenous clastics of the Endicott Group.

The plutons and associated strata in the southern Brooks Range are parautochthonous to allochthonous with respect to the Yukon Fold Belt to the north (Mull et al., 1987). Their present position resulted from Mesozoic overthrusting onto the parautochthonous upper Paleozoic strata that were deposited on the Yukon Fold Belt. The volcanics, plutons and metasediments probably developed in an ensialic island arc or submerged continental margin environment (Dillon et al., 1980).

Ancestral Aklavik Arch

The northeast-trending Ancestral Aklavik Arch developed on the southeastern part (present day position) of the Yukon Fold Belt during the latest Carboniferous (Kasimovian? and Gzhelian), and the southwestern part of the arch was subaerially exposed into the Late Permian. During the Early Permian, the

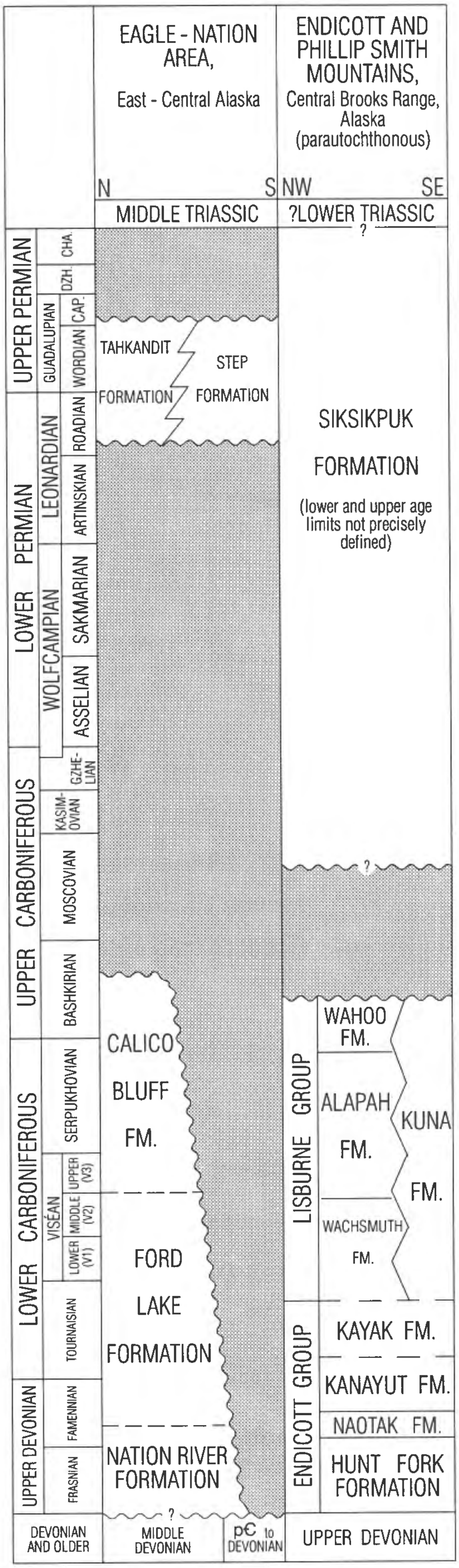


Figure 8.4. *Correlation of Upper Devonian, Carboniferous, and Permian lithostratigraphic units in east-central and northeastern Alaska with standard chronostratigraphic units (from Brabb, 1969; Brabb and Grant, 1971; Mull et al., 1987; Brosgé et al., 1988; Armstrong and Mamet, 1978).*

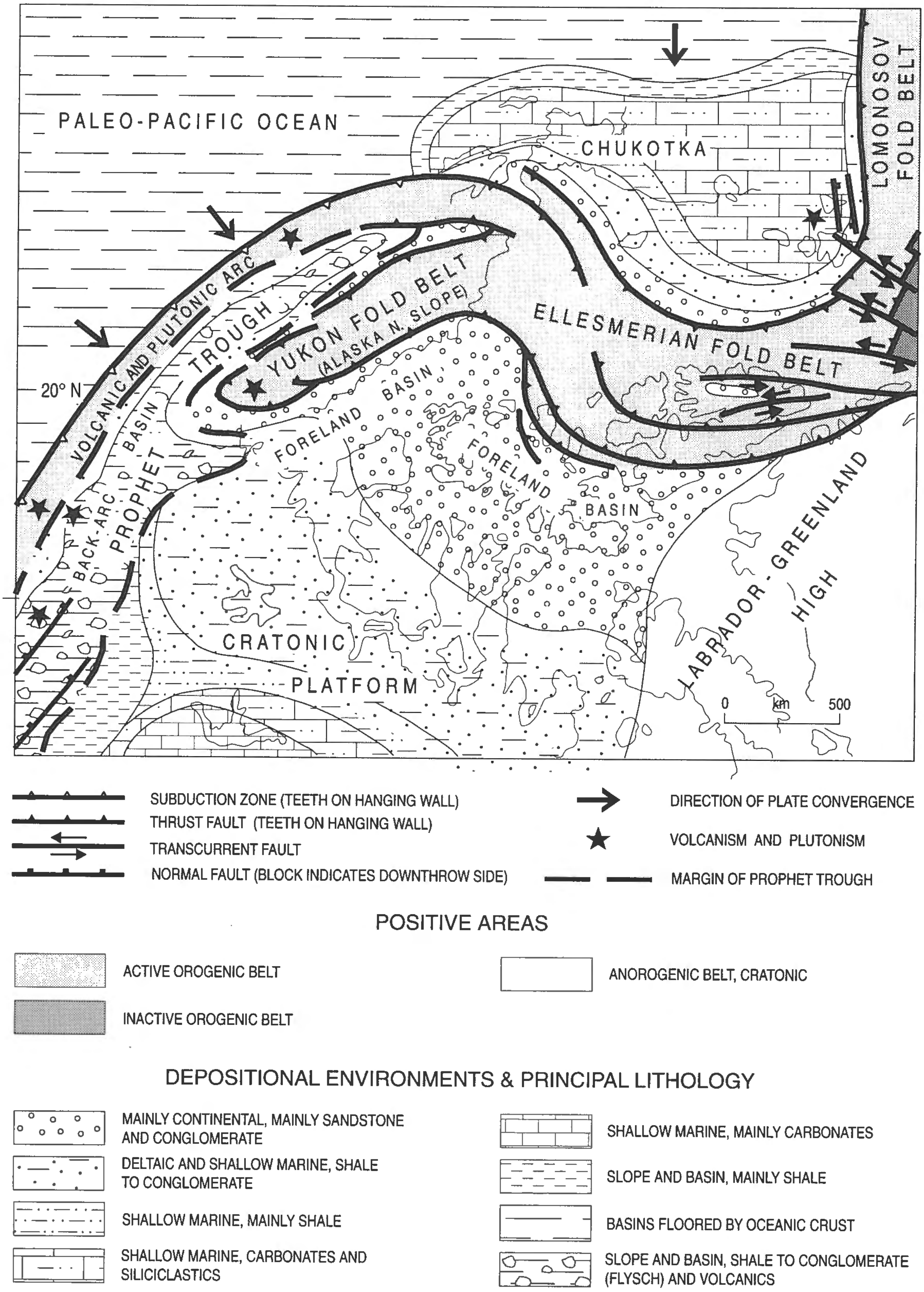


Figure 8.5. *Paleogeographic map showing principal latest Devonian (late Famennian) and earliest Carboniferous (early Tournaisian) tectonic elements, lithofacies and latitude in the study area and adjacent regions (modified from Ziegler, 1988, fig. 6).*

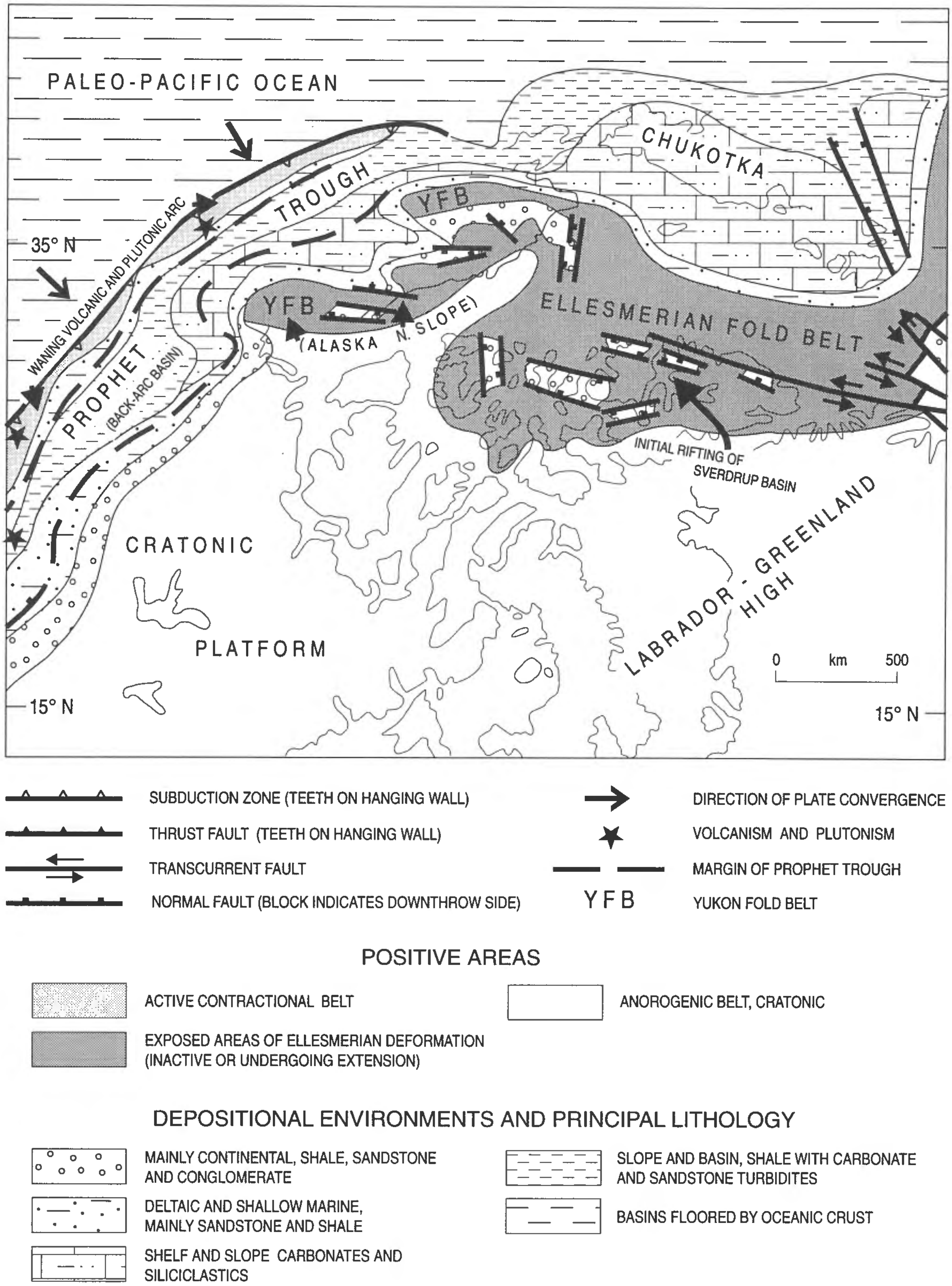


Figure 8.6. *Paleogeographic map showing principal Early Carboniferous (late Viséan) tectonic elements, lithofacies and latitude in the study area and adjacent regions (modified from Ziegler, 1988, fig. 7).*

arch lay north of the Ishbel Trough and south of an unnamed extensional successor basin that was probably connected with the extensional Sverdrup Basin.

The Ancestral Aklavik Arch, a regional structure that Jeletzky (1963) interpreted to be the predecessor of the Mesozoic Aklavik Arch, extends northeastward from the Tintina Fault in east–central Alaska to northwest District of Mackenzie, where it plunges beneath the Mackenzie Delta (D.K. Norris, 1973; Bamber and Waterhouse, 1971). The Alaskan extension of the Ancestral Aklavik Arch is generally called the Dave Lord Creek Arch (Brosgé and Dutro, 1973), and in the study area, the name Dave Lord High has been used recently (A.W. Norris, 1985, p. 41).

A fault block origin for the Ancestral Aklavik Arch is suggested by the preservation of thick Carboniferous and Permian deposits in structural lows on either side of the uplift, and the presence on the arch of Carboniferous remnants preserved partly in grabens. The arch is partly bounded by steeply dipping strike-slip faults recording pre- and post-Permian movement.

This feature was, therefore, probably a series of uplifed blocks and not a true structural arch (broad anticlinal fold). A latest Carboniferous origin for the Ancestral Aklavik Arch is recorded by the preservation of Kasimovian(?) and Gzhelian conglomerate immediately south of the arch and by the occurrence of sub-Permian erosional remnants of Carboniferous units on the arch in the study area (D.K. Norris, 1981b, d, 1985) and east–central Alaska (Brosgé and Dutro, 1973, p. 370–371). Subsequent to the earliest Permian, the arch was largely transgressed and the only part of the uplift that persisted into the Late Permian lay in east-central Alaska.

Prophet Trough

The name Prophet Trough was introduced by Richards (1989) for the downwarped and downfaulted western margin of North America in the Late Famennian and Carboniferous. In the study area, the trough developed on northern Mackenzie Basin (Morrow and Geldsetzer, 1988), which included an axial graben called the Richardson Trough. Prophet Trough was continuous with the Antler Foreland Basin of the western United States, and extended from southeastern British Columbia to the Yukon Fold Belt.

The pericratonic Prophet Trough, at least in part a compressional foreland basin during the latest Devonian and earliest Carboniferous, apparently had a predominantly extensional history. The trough developed in the foreland of an ensialic arc or continental margin volcanic/plutonic belt resulting from plate convergence and eastward-directed subduction. The volcanic/plutonic belt, preserving Late Devonian and Early Carboniferous granitoid plutons (Richards, 1989), may have been continuous with the mid-Paleozoic parautochthonous volcanic/plutonic belt preserved in the southern Brooks Range, as shown by the Famennian paleotectonic reconstruction of Ziegler (1988; Fig. 8.5). During the Late Devonian and earliest Carboniferous, northern Prophet Trough was probably a compressional foreland basin because it received coarse syntectonic siliciclastics from the Yukon Fold Belt and subsided in response to orogenic compression related to the Ellesmerian Orogeny. After the earliest Carboniferous, however, northern Prophet Trough was probably predominantly an extensional basin.

The distribution of uppermost Devonian and Carboniferous facies in the study area suggests that the Prophet Trough bifurcated at the Yukon Fold Belt (Figs. 8.5, 8.6). One arm was basically an embayment that probably extended only a short distance northeastward. It did not extend as far northeastward as its Devonian predecessor, but still lay in the foreland of the Yukon and Ellesmerian fold belts. The other arm, in which most of the Carboniferous in the Brooks Range of Alaska was deposited, developed along the northwest side (Paleozoic position) of the Yukon Fold Belt.

Ishbel Trough

After the Moscovian, most of the region occupied by the Prophet Trough was exposed to deep subaerial erosion, but during the Early Permian, the Ishbel Trough of Henderson (1989) and Henderson et al. (1993) developed in much of the area formerly occupied by the Prophet Trough. The Ishbel Trough, a result of regional subsidence accompanied by a rise in sea level, extended from southern British Columbia to the Ancestral Aklavik Arch during the earliest Permian and farther northward by the Late Permian. Like the Prophet Trough, the younger trough apparently bifurcated in the north. The Ishbel Trough developed in a dominantly extensional, ensialic back-arc setting (Richards, 1989, fig. 9.34; Henderson et al., 1993).

Cratonic platform

The western cratonic platform was a broad, relatively stable element extending northward from the southern

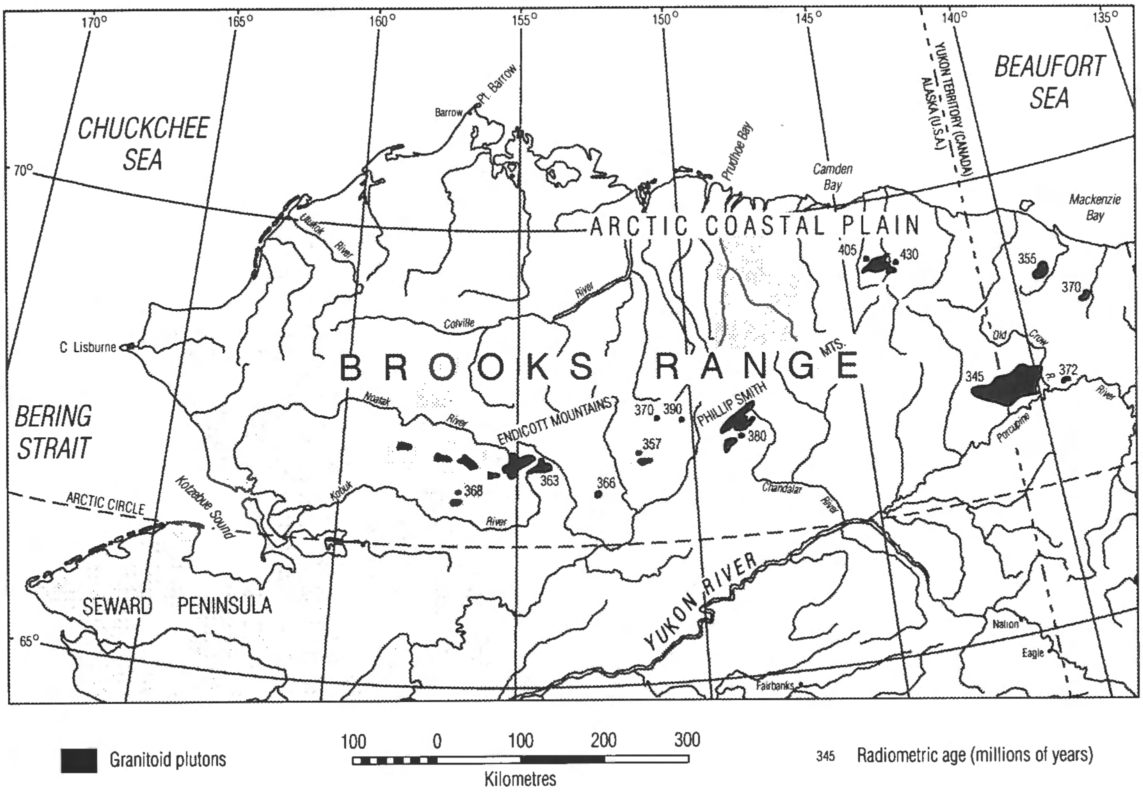


Figure 8.7. *Generalized map of northern Alaska and Yukon Territory showing: principal geographic elements, location of Devonian and earliest Carboniferous granitoid plutons, and localities with dated middle Paleozoic volcanics (from Dillon et al., 1980, fig. 1).*

part of the North American Plate to the Devonian Mackenzie Basin and its successor, the northeastern Prophet Trough. The northwestern part of the cratonic platform, which lay in the foreland of the Yukon and Ellesmerian fold belts, has been called the Mackenzie Platform (A.W. Norris, 1985, p. 38) and Peel Shelf (Morrow and Geldsetzer, 1988, fig. 16).

Paleogeographic reconstructions

The Late Devonian (Famennian) and Early Carboniferous (Viséan) paleotectonic/paleogeographic reconstructions of Ziegler (1988) are the most comprehensive of the numerous middle to late Paleozoic reconstructions proposed (Nilsen, 1981, p. 207–215) for northern Yukon and Alaska (Figs. 8.5, 8.6). His reconstructions, based on numerous regional and local studies, accommodate the present data better than all others.

According to Ziegler's reconstructions, the Yukon Fold Belt was continuous with the Ellesmerian or Inuitian Fold Belt of the Canadian Arctic Archipelago, and lay northwest of the southwestern Canadian Arctic islands. Counter-clockwise rotation, starting between the Early Jurassic and Early Cretaceous, brought the Yukon Fold Belt to its Holocene position (Nilsen, 1981; Ziegler, 1988; Embry, 1988; Mayfield et al., 1988). The pole of rotation is assumed to be in the western part of Mackenzie River Delta area, but evidence for the location of this pole is inconclusive (Tailleur, 1969a, b; Mayfield et al., 1988, p. 169). D.K. Norris (1987) related the rotation of the Arctic Alaska Plate to the opening and stretching of the supracrustal wedge to form the Rapid Depression and identified the pole of rotation at the apex of the depression (lat. 68°N, long. 137°W).

Ziegler's Famennian reconstruction shows the Yukon Fold Belt as an orogenic belt with double vergence. A Frasnian to Tournaisian compressional foreland basin—northern Mackenzie Basin and its successor, the northeast arm of Prophet Trough—was present on the southeast side of the Yukon Fold Belt. A Famennian to Tournaisian basin—the western arm of Prophet Trough and its Devonian predecessor—lay northwest of the fold belt but inboard of a second contractional belt resulting from southeastward-directed subduction. This second contractional belt is represented by Late Devonian granitoid plutons and associated volcanics preserved in the southern Brooks Range of Alaska (Dillon et al., 1980).

The ensialic back-arc basin between the two orogenic belts received a thick Frasnian to Tournaisian succession of marine to fluvial conglomerate, sandstone, and shale preserved in the parautochthonous Hunt Fork and overlying Kanayut Formation of the Endicott Group (Nilsen, 1981, p. 209). Subsidence in this back-arc basin probably resulted largely from compression, but episodes of block-faulting are common in this style of basin and may have occurred (Einaudi and Hitzman, 1986). During the Tournaisian, the sea transgressed the fluvial lithofacies of the central basin and part of the flanking highlands.

The post-Tournaisian, late Paleozoic tectonic setting resembled that of the Famennian and Tournaisian, but the orogenic belts were inactive and gradually transgressed; in addition, extensional uplifts (e.g., Ancestral Aklavik Arch) and basins were present (Fig. 8.6). Part of the northern Yukon Fold Belt or Barrovia—the area of the present outer Beaufort Shelf and farther north—remained subaerially exposed during most of the late Paleozoic and provided siliciclastics. If the rotation hypothesis discussed above is correct, that positive belt, called Crockerland by Embry (1992), would have formed the western rim of the developing extensional Sverdrup Basin.

Stratigraphy

Upper Devonian and Carboniferous

Stratigraphic framework and unconformities

A thick succession of Frasnian to Moscovian carbonates and siliciclastics lacking documented major internal unconformities is widely preserved beneath Permian strata in the northern Cordillera north of latitude 64°30′N (Figs. 8.1-8.4). Younger Carboniferous deposits occur only in the northwestern Ogilvie Mountains, where Kasimovian to Gzhelian strata are present (Fig. 8.8; Waterhouse and Waddington, 1982). Upper Devonian strata are widely distributed south of the Ancestral Aklavik Arch, but earliest Carboniferous (Tournaisian) strata have been definitely identified only in southwestern Peel Plateau (Bamber and Waterhouse, 1971, p. 50). They may also be present on the western flank of the southern Richardson Mountains (Pugh, 1983, p. 45) and in the basal siliciclastics of the western British Mountains (Figs. 8.2, 8.8, 8.9).

The Upper Devonian and Carboniferous of the northern Cordillera comprises two closely related assemblages. These assemblages were originally continuous, but are now separated geographically by the Ancestral Aklavik Arch, along which they were truncated beneath the regional sub-Permian disconformity. Both assemblages comprise a lower interval dominated by terrigenous clastics and an upper one consisting mainly of carbonates.

The more completely preserved of the two assemblages consists of autochthonous and parautochthonous Frasnian to Gzhelian strata occurring south of latitude 67°30′N in the Ogilvie Mountains and Eagle Plain, and on the flanks of the southern Richardson Mountains (Figs. 8.1, 8.2, 8.8). This southern assemblage closely resembles the parautochthonous sequence of the southern Brooks Range in Alaska (Fig. 8.4) and was deposited in the southeastern part of the same basin (Figs. 8.5, 8.6). In Canada, most of the Devonian strata were deposited in the northern Mackenzie Basin and on the Peel Shelf. Deposition of the Carboniferous component of the assemblage occurred in northern Prophet Trough and possibly on western Peel Shelf.

The second assemblage consists principally of Viséan to Moscovian strata that onlap from the Prophet Trough northwestward (Paleozoic position) onto the Yukon Fold Belt and possibly northeastward toward the cratonic platform. This second assemblage closely resembles the parautochthonous northern Brooks Range succession and the succession preserved on the Alaskan North Slope and continental shelf (Figs. 8.2, 8.9). It occurs mainly north of latitude 68°00′N in a southeast-trending, discontinuous belt extending from the Yukon/Alaska border into northwestern District of Mackenzie.

The two assemblages in the study area originally formed part of a continuous depositional complex. Their distribution has been altered by the probable counter-clockwise rotation of northern Yukon and Alaska during the Mesozoic and by minor, dextral transverse movement along the Kaltag–Porcupine Fault during the Mesozoic and Cenozoic (Norris and Yorath, 1981). The assemblages are now almost entirely separated by the northeast-trending, late Paleozoic Ancestral Aklavik Arch (Bamber and Waterhouse, 1971). To emphasize the close similarity and former geographic continuity of the two assemblages, the name Endicott Group, which originally applied to the Alaskan succession and the deposits of northernmost Yukon, is herein extended to include the lithologic and stratigraphic equivalents of the southern assemblage (Imperial, Tuttle, and Ford Lake formations; Figs. 8.2,

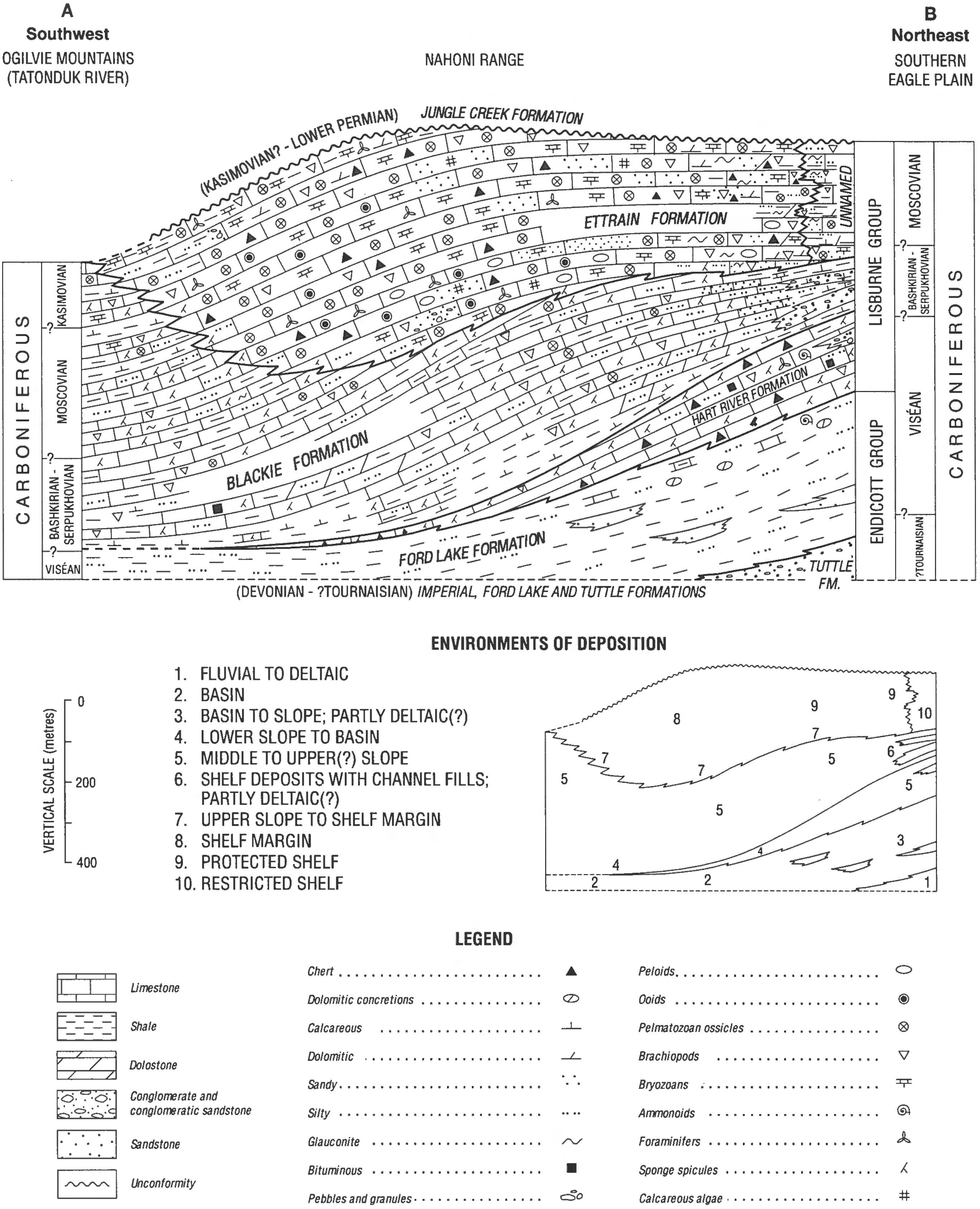


Figure 8.8. *Partly schematic stratigraphic cross-section A–B showing the Carboniferous of the Ogilvie Mountains and southern Eagle Plain (from Richards et al., 1993, fig. 4E.22). See Figure 8.1 for the line of section.*

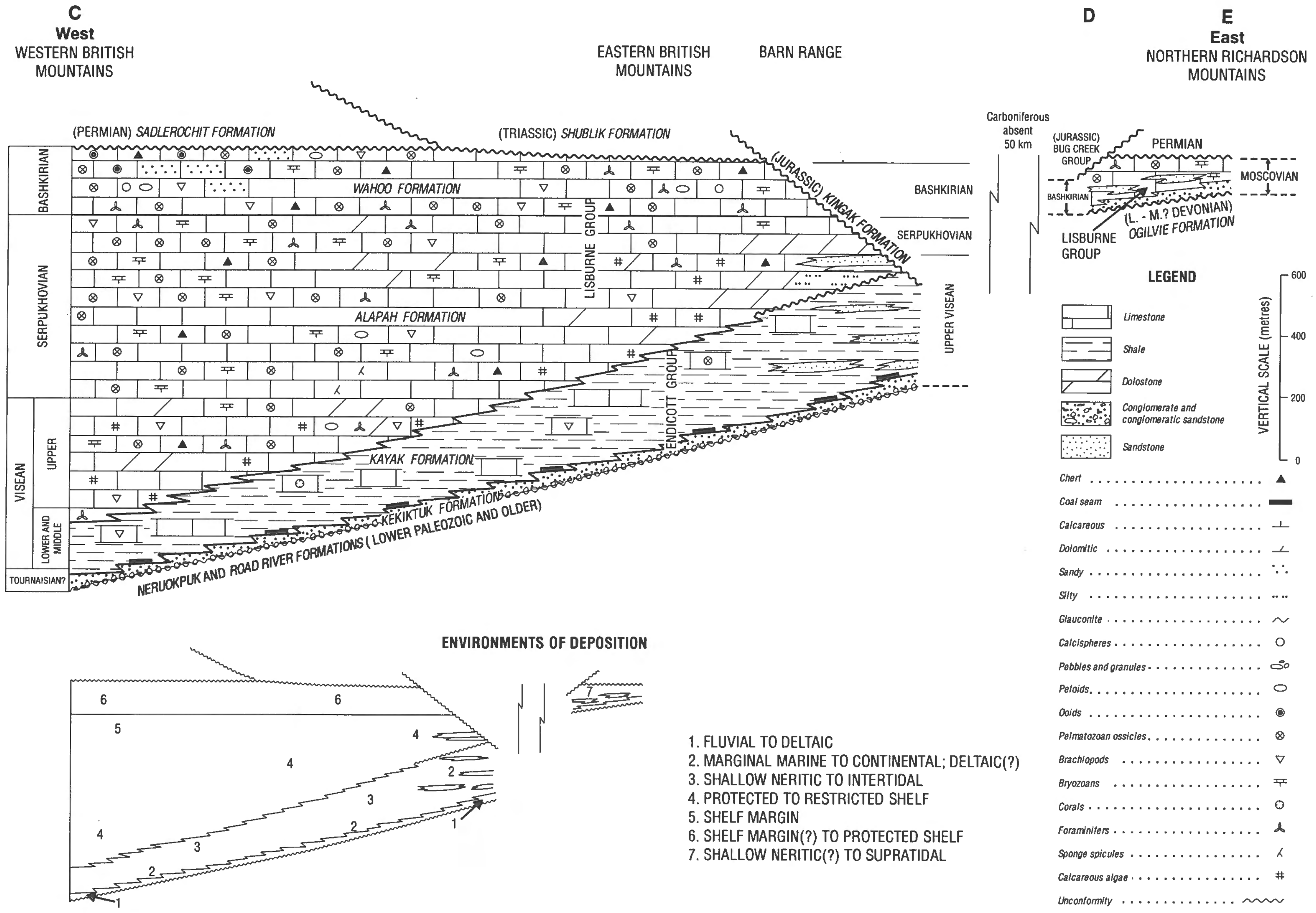


Figure 8.9. *Partly schematic stratigraphic cross-section C–D–E showing the Carboniferous of the British Mountains and the northern Richardson Mountains (from Richards et al., 1993, fig. 4E.23). See Figure 8.1 for the line of section.*

8.8). Similarly, the name Lisburne Group is extended to include the correlative equivalent carbonates and associated siliciclastics of the southern assemblage (Hart River, Blackie, and Ettrain formations). The Endicott and Lisburne groups in northern Alaska were first described by Bowsher and Dutro (1957).

The lower boundary of the southern assemblage is a conformity, whereas that of the northern assemblage is a regional unconformity of substantial magnitude (Figs. 8.2, 8.8, 8.9). In the south, the Upper Devonian Imperial Formation of the Endicott Group conformably overlies Middle Devonian marine shale and mudstone of the Canol Formation, which in turn unconformably overlies Middle Devonian strata in the eastern part of the study area (A.W. Norris, 1985). In the southern Brooks Range of eastern Alaska, the Endicott Group (Fig. 8.4) comprises parautochthonous correlatives of this southern assemblage and generally conformably overlies Middle to Upper Devonian marine shale and carbonates of the Beaucoup Formation (Brosgé et al., 1988). In contrast, the northern assemblage of the Yukon and correlative strata in the parautochthonous succession of northern Alaska unconformably overlie lower Paleozoic and Precambrian strata deformed and intruded during the Ellesmerian Orogeny. This regional unconformity, mainly an angular unconformity, increases in magnitude toward the north and resulted from Late Devonian and Carboniferous, deep, subaerial erosion.

Within most of the study area, the upper boundary of the Upper Devonian and Carboniferous succession is a sub-Permian regional unconformity resulting from latest Carboniferous and Early Permian subaerial erosion (Figs. 8.2, 8.8). Triassic to Lower Cretaceous strata unconformably overlie the package in the east and northeast (Fig. 8.9; Bamber and Waterhouse, 1971; D.K. Norris, 1983; Pugh, 1983). The sub-Permian break resulted mainly from a latest Carboniferous to earliest Permian lowstand of global sea level (Veevers and Powell, 1987) and from contemporaneous uplift of the Ancestral Aklavik Arch. The magnitude of this hiatus is greatest along the axis of Ancestral Aklavik Arch, where Carboniferous deposits were almost completely removed and Permian strata generally overlie Devonian and older rocks. In the northwestern Ogilvie Mountains, where latest Kasimovian and Gzhelian deposits are preserved in the lower Jungle Creek Formation, deposition may have been continuous across the Carboniferous/ Permian boundary. In the latter area, however, some erosion is suggested by the occurrence of thick conglomerate units in the lower Jungle Creek. In northern Alaska, the boundary between the Carboniferous and Permian is also a regional subaerial unconformity (Brabb and Grant, 1971; Brosgè and Dutro, 1973; Detterman et al., 1975). In the northeastern part of the study area, both Carboniferous and Permian strata are truncated northeastward beneath regional, sub-Triassic and sub-Jurassic unconformities (D.K. Norris, 1983). Northeast of the erosional edge of the Permian (Fig. 8.1), the southern assemblage is truncated northeastward beneath a regional sub-Cretaceous subaerial unconformity (Pugh, 1983).

Southern Assemblage. The basal part of the southern assemblage comprises Frasnian to Viséan siliciclastics of the Endicott Group (Imperial, Tuttle and Ford Lake formations; Figs. 8.2, 8.8). These are overlain by upper Viséan to Kasimovian(?) carbonates and siliciclastics of the Lisburne Group, which includes the Hart River, Blackie and Ettrain formations. The youngest Carboniferous deposits of the study area occur in the westernmost Ogilvie Mountains, where the Lisburne is overlain by Kasimovian(?) to Gzhelian terrigenous clastics of the basal Jungle Creek Formation.

Imperial Formation. At the base of the southern succession, thick, dominantly fine grained siliciclastic rocks and subordinate silty limestone of the Imperial Formation (Hume and Link, 1945) conformably overlie marine shale and mudstone of the Canol Formation (Figs. 8.2, 8.10; Chapter 7). The lower Frasnian to uppermost Famennian (Strunian) Imperial Formation (Braman, 1981; Pugh, 1983, p. 42; A.W. Norris, 1985, p. 34-36) is widely distributed in the Eagle Plain, on the flanks of the Richardson Mountains and in the northwestern Interior Plains. It also outcrops in the western Keele Range of the northern Ogilvie Mountains (D.K. Norris, 1985). The Imperial attains a maximun known thickness of 1909 m on the east flank of the northern Richardson Mountains and thins southwestward to a zero edge below the Ford Lake Shale (Pugh, 1983, p. 42, fig. 17). This thinning probably resulted from a facies change to shale of the Ford Lake Formation.

Along the northeastern flank of the Mackenzie Mountains, the flanks of the Richardson Mountains, and in the Eagle Plain, the Imperial is generally abruptly overlain by deltaic to fluvial lithofacies of the Tuttle Formation. Strata that are probably assignable to the Tuttle also overlie the Imperial in the Keele Range. On the Trail River, and possibly elsewhere, the base of the overlying Tuttle is unconformable (A.W. Norris, 1985, p. 34; Braman, 1981). In all of these areas, the Imperial/Tuttle contact is placed at the first appearance of conglomerate. Near its south-

***Figure 8.10.** Siltstone, sandstone, and mudstone turbidites in the Upper Devonian Imperial Formation near McDougal Pass, northern Richardson Mountains (lat. 67°40′N, long. 136°19′W). GSC photo 114787.*

western depositional zero edge in the Eagle Plain, the Imperial Formation (Pugh, 1983) is directly overlain by marine shale of the Ford Lake Formation.

In the northern Richardson Mountains, highly folded Imperial strata are unconformably overlain by coarse grained Permian terrigenous clastics (A.W. Norris, 1968, p. 282). Pre-Permian deformation of the Imperial possibly resulted from the Ellesmerian Orogeny (A.W. Norris, 1968, p. 280), but may have been caused by development of the adjacent Ancestral Aklavik Arch during the latest Carboniferous and Early Permian. The Imperial Formation is unconformably overlain by Cretaceous deposits over much of the northern Mackenzie River region to the east.

The Imperial Formation is basically a progradational, coarsening-upward succession comprising shale, grading upward into siltstone and subordinate sandstone (chertarenite; classification of Folk, 1974), and limestone. The major components of most sections are dark grey marine shale, silty shale, and argillaceous siltstone (Fig. 8.10). Minor coarse grained siltstone and very fine to fine grained sandstone occur in many areas, and coarser grained sandstone becomes common northeastward. Siltstone and sandstone become more abundant upward and northward. These rock types commonly occur as sharp-based graded beds that display basal flute casts and other features characteristic of turbidites (Hills and Braman, 1978; Braman, 1981; Pugh, 1983; A.W. Norris, 1985).

In the study area, the synorogenic deposits of the Imperial Formation probably record deposition in moderately deep water (mainly below storm wave-base) basin, slope, and shelf environments in the foreland of the rising Yukon and Ellesmerian fold belts. This interpretation is in general agreement with those of Ziegler (1969) and Glaister and Hopkins (1974). The Imperial resembles the largely coeval Hunt Fork Formation (Fig. 8.4) of the southern Brooks Range and was in part deposited in the same flysch trough. The Hunt Fork contains thin bedded turbidites deposited in slope or prodelta environments (Brosgé et al., 1988, p. 303).

Tuttle Formation. Thick, coarse to fine grained siliciclastics of the Tuttle Formation (Pugh, 1983) abruptly overlie the Upper Devonian Imperial Formation in the Eagle Plain and on the flanks of the Richardson Mountains (Figs. 8.2, 8.8, 8.11, 8.12). Strata that are probably assignable to the Tuttle but were provisionally mapped as the Kekiktuk Formation (D.K. Norris, 1981d) are preserved in the Keele Range. The Tuttle is mainly Famennian, but may contain strata as young as middle Tournaisian in its upper part (A.W. Norris, 1985, p. 36-38; Pugh, 1983; Braman, 1981). On the east side of the Eagle Plain, a maximum known thickness of 1421 m is attained by the southwestward fining Tuttle Formation (Pugh, 1983). The isopach map of the Tuttle (Pugh, 1983, fig. 18) suggests the depocentre of the formation was the northwest-trending Richardson Trough, presently the site of the Richardson Anticlinorium.

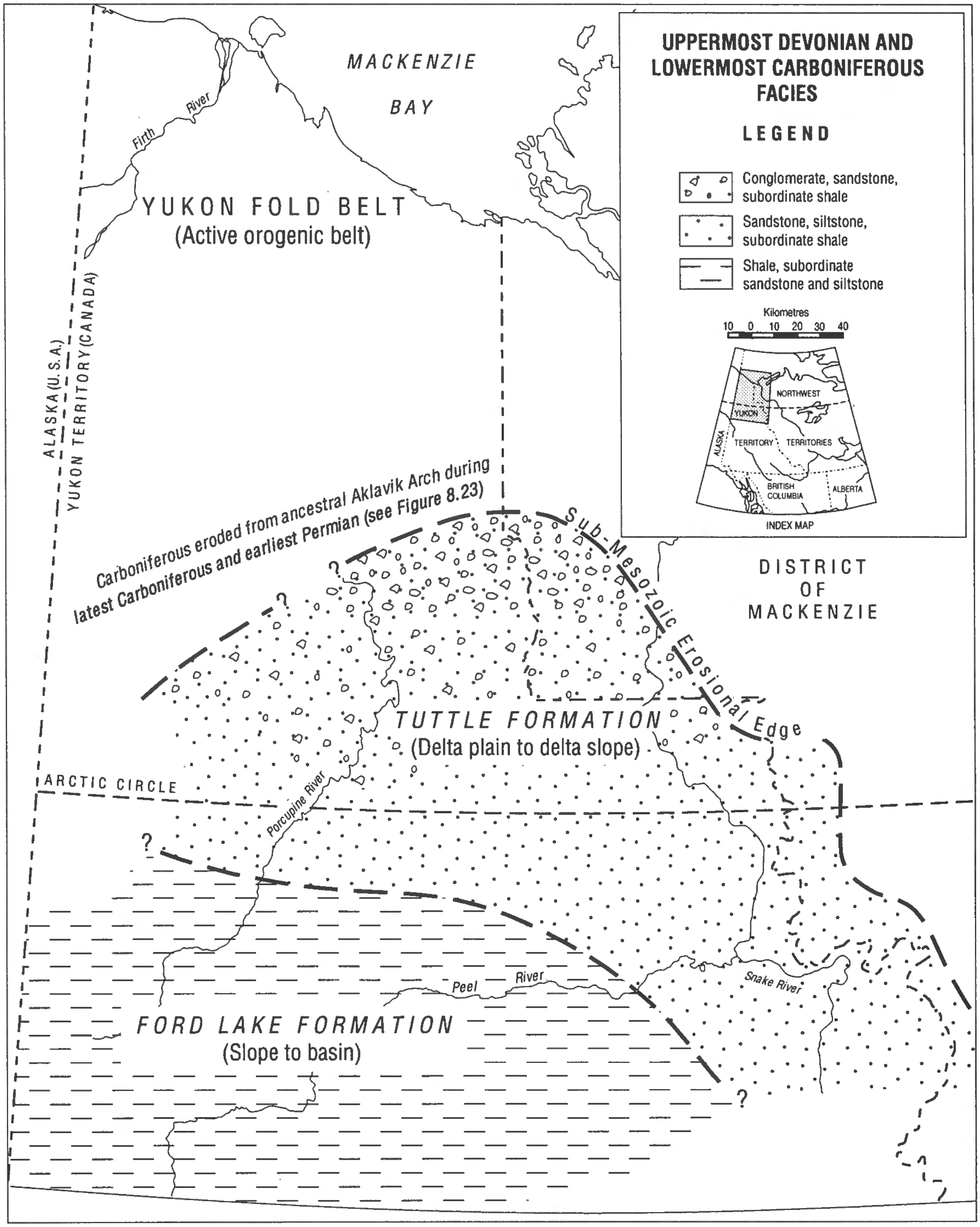


Figure 8.11. *Generalized facies distribution map (lower to middle Tournaisian), Tuttle and Ford Lake formations (not palinspastically restored). See Figure 8.1 for the present-day distribution of Carboniferous deposits and Figure 8.2 for the stratigraphic level.*

The Tuttle Formation is generally unconformably overlain by Lower Cretaceous terrigenous clastics from which it is commonly difficult to distinguish (Pugh, 1983, p. 44). In southern Eagle Plain and on the flanks of the southern Richardson Mountains, however, the Tuttle is conformably overlain by the Ford Lake Formation (Pugh, 1983; D.K. Norris, 1985). Elsewhere in the study area, mainly on the flanks of the southern Richardson Mountains, the top of the formation is the present-day erosion surface.

Figure 8.12. Tuttle Formation, Dempster Highway, east side of Eagle Plain. The outcrop comprises conglomerate and conglomeratic sandstone channel-fills (arrows) and intervening units of shale mudstone and sandstone; the man on the left indicates scale. ISPG photo 2049–71.

Chert granule to pebble conglomerate (Fig. 8.12) and conglomeratic sandstone (chertarenite) with subordinate siltstone and shale constitute the Tuttle in most sections. Minor coal is locally present, and scattered terrestrial plant remains are preserved. In several sections, Pugh (1983, figs. 32b, 34) included hundreds of metres of shale in the upper Tuttle. These upper deposits closely resemble those of the overlying Ford Lake Formation and may be assignable to that unit. Several moderately thick (>25 m) shale units lie at other levels in the formation as well.

Gamma-ray/sonic logs and well cuttings record the presence of numerous thick (commonly >30 m), sharp-based sequences of conglomerate and conglomeratic sandstone grading upward into argillaceous sandstone, siltstone and shale. The lower, coarse-clastic components of these sequences, which are commonly stacked and become less abundant southwestward, are interpreted to be channel fills. Coarsening-upward sequences of shale grading upward into siltstone and sandstone are common as well, particularly in the southwest. Sequences of this type develop in several environments including: shoreline, delta-front, and slope. Sequences similar to those in the subsurface are widely exposed in the outcrop belt (Fig. 8.12). Hills and Braman (1978, p. 36) reported the presence of coarse grained, normally graded clastic units on the Trail River that they interpreted to be of sediment gravity flow origin. The upper Tuttle becomes finer grained as it passes upward and southwestward into marine shale and siltstone of the Ford Lake Formation.

The granule to cobble fraction in the Tuttle is mainly light grey chert (Fig. 8.13), but green to greenish grey clasts are common. Siltstone and sandstone are next in abundance, constituting 1 to 5 per cent of the granule to cobble fraction. Chert clasts predominate in the sandstone matrix of the conglomerate. Quartz is next in abundance (25–30%); feldspar, heavy accessories, and mafic minerals are minor constituents. Within the fine to coarse sand-sized quartz fraction, very angular to subangular clasts (mainly first-cycle clasts) are slightly more abundant than those that are subrounded to well rounded (second- or multi-cycle quartz). Sand-sized metamorphic quartz grains with undulatory extinction (>5°) are common (20–25%). Fine to coarse sand-sized clasts of plutonic quartz with more than three crystals are present but not abundant (1–3%). The clast composition of the conglomerate closely resembles that of the Kekiktuk Formation in the northern assemblage and the Kanyut Formation in Alaska (Brosgé et al., 1988, p. 308–309).

The characteristics and regional relationships of the Tuttle indicate deposition in prodelta, deltaic and related fluvial environments (Lutchman, 1977; Pugh, 1983) in a molasse trough south of the topographically high Yukon Fold Belt (Fig. 8.5). Tuttle lithofacies closely resemble fluvial and deltaic deposits of the Famennian to Tournaisian(?) Naotak Formation and overlying Kanayut Conglomerate in the southern Brooks Range (Nilsen, 1981; Brosgé et al., 1988). They are also similar to the sandstone, conglomerate and mudstone of the Upper Devonian Nation River Formation (Brabb and Churkin, 1967) of east-central Alaska. These four formations were probably part of the same lithosome prior to their partial removal by latest Carboniferous and Permian erosion. Paleogeographic reconstructions by Ziegler (1988) suggest that the Tuttle was deposited mainly in the northeastern arm of Prophet Trough and its Devonian predecessor (northern Mackenzie Basin), while deposition of the Naotak, Kanayut and Nation River took place in the northwestern arm.

The progradational/aggradational deposits of the lower and middle Tuttle, Naotak and Kanayut formations jointly constitute the upper part of a thick, transgressive/regressive succession (Canol to middle Tuttle and correlatives) resulting from the initial to culminating phases of the Ellesmerian Orogeny. Overlying, retrograding lithofacies in the upper Tuttle and Kanayut record a waning influx of terrigenous clastics from the Yukon and Ellesmerian fold belts and the early phase of a subsequent regional transgression. The transgression culminated with deposition of the overlying fine grained marine facies of the Ford Lake and Kayak formations.

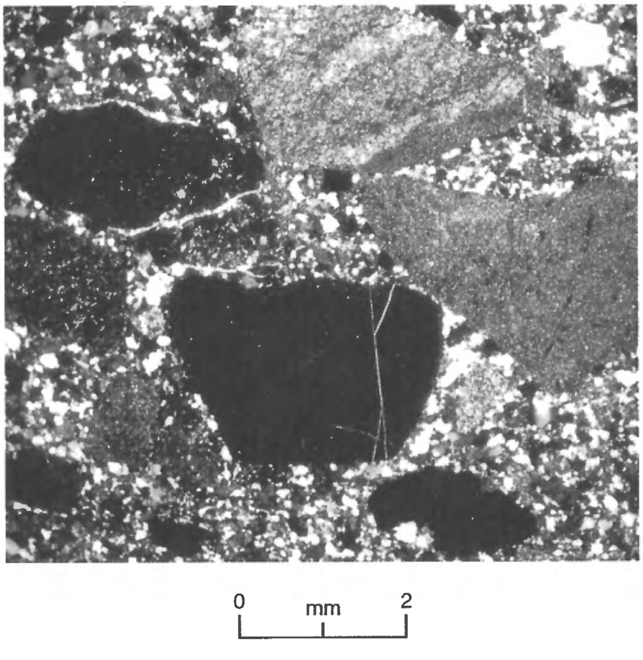


Figure 8.13. *Photomicrograph of chert-pebble conglomerate from the Tuttle Formation on the east side of the Richardson Mountains (GSC loc. 6606). Matrix of conglomerate is siliceous chertarenite. ISPG photo 3509-82.*

Ford Lake Formation. The Upper Devonian to upper Viséan (V3) Ford Lake Formation (Brabb, 1969) of the study area comprises up to 975 m of fine grained siliciclastics (Figs. 8.2, 8.8, 8.11, 8.14). These deposits, thickest south of the sub-Cretaceous erosional edge of the overlying Viséan Hart River Formation, are distributed over a wide area including the west flank of the Richardson Mountains, southern Eagle Plain, and the Ogilvie Mountains (Pugh, 1983, figs. 16, 17). Tournaisian strata have not been identified but may be present because there is no definite evidence for a disconformity at the base of the Carboniferous, and the underlying Tuttle Formation may be as young as middle Tournaisian.

The Ford Lake shale is a stratigraphic and lithologic equivalent of the Kayak Formation, preserved in Alaska and in the northern assemblage of Yukon. Prior to deep latest Carboniferous and Permian erosion, these units were probably contiguous. Based on Ziegler's (1988, fig. 6) reconstruction of the Viséan, Carboniferous lithofacies of the Ford Lake Formation were deposited in eastern Prophet Trough while the Kayak of the Brooks Range was deposited in the northwestern arm.

In the north, the Ford Lake Formation conformably overlies, and grades northward into, the Tuttle Formation. Southwest of the basinward zero edge of the Tuttle, it conformably overlies the Imperial Formation. The upper Ford Lake grades upward and northeastward into spiculitic carbonates of the lower Hart River Formation (Figs. 8.2, 8.8). Northward from the erosional zero edge of the Hart River Formation, the Ford Lake shale is rapidly truncated beneath Lower Cretaceous strata.

The Ford Lake Formation consists of dark grey to black, silty, pyritic shale and siltstone with subordinate sandstone (subchertarenite and chertarenite), conglomerate, and silty limestone (Pugh, 1983, p. 45). The clast composition of the sandstone resembles that of the Tuttle sandstone, but the ratio of quartz to chert grains is greater in Ford Lake sandstones.

The lithology and lithofacies relationships of the Ford Lake Formation record deposition mainly in a moderately deep water, basinal environment similar to

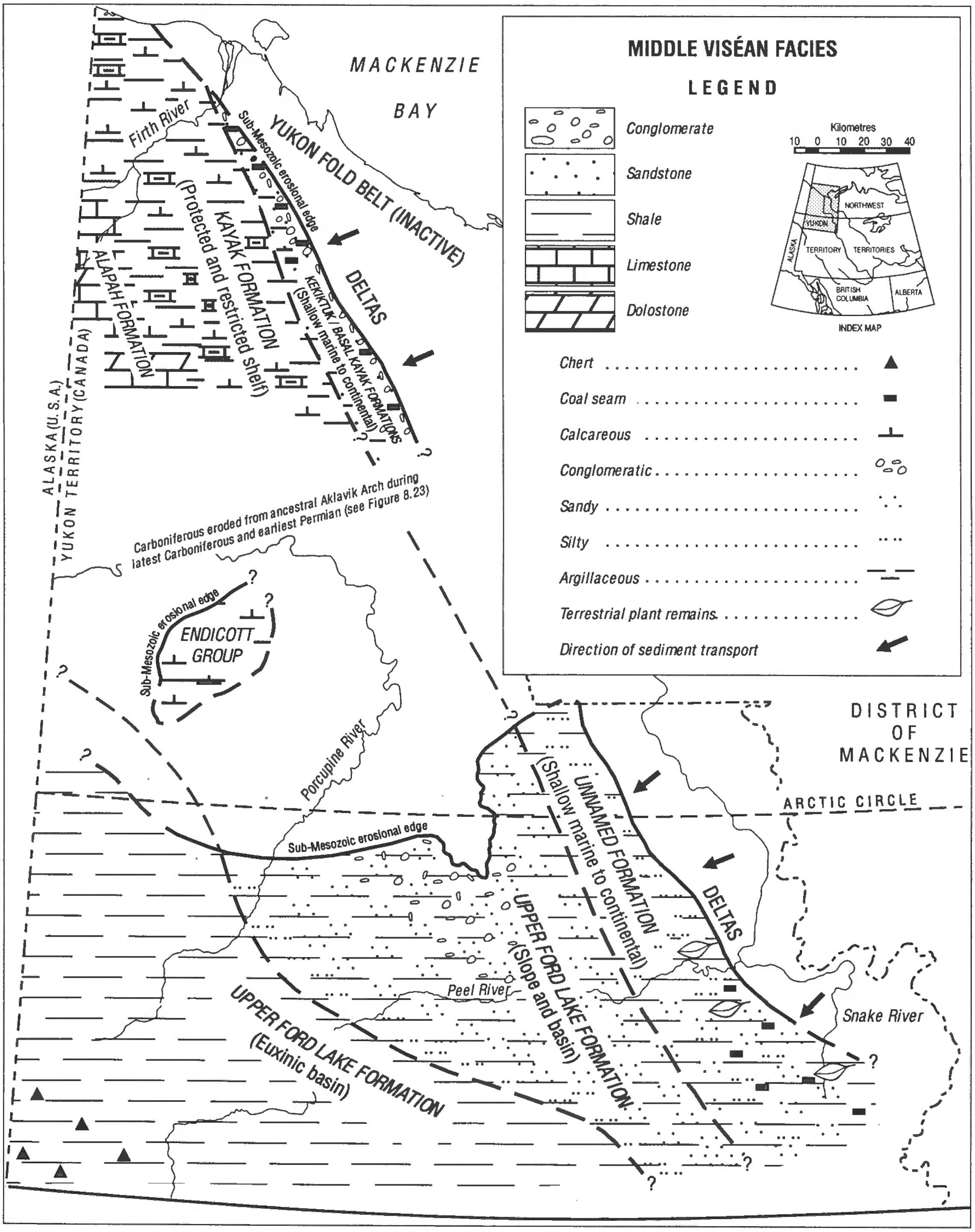


Figure 8.14. *Generalized facies distribution map (middle Viséan), upper Ford Lake Formation, Kekiktuk and Kayak formations, and basal Alapah Formation (not palinspastically restored). See Figure 8.1 for the present-day distribution of Carboniferous deposits and Figure 8.2 for the stratigraphic level.*

that represented by the Besa River Formation in more southerly parts of the Cordillera (Richards, 1989). Basal deposits of the formation and some coarsening-upward sandstone units higher in the formation grade northward into deltaic deposits of the Tuttle Formation, suggesting that they were probably deposited in relatively shallow water prodelta and delta-front settings. Viséan sandstone and conglomerate occurring in the upper part of the eastern Ford Lake Formation form wedges and lenses that thin southward or basinward (Graham, 1973) and may have been deposited partly in delta-slope environments.

Shale and siltstone of the lower Ford Lake Formation onlap eastward and northward over deltaic and related facies of the Tuttle Formation, thereby indicating an early Carboniferous transgression. The early phase of this transgression coincided in part with the regional early middle Tournaisian transgression recorded by the lower Banff Formation of southwestern Canada (Richards, 1989).

Unnamed correlatives of the eastern Ford Lake Formation occur in southwestern Peel Plateau (Bamber and Waterhouse, 1971, p. 50). They consist of up to 1300 m of middle(?) Tournaisian and Viséan, cyclic, marine and nonmarine (deltaic) shale, siltstone, sandstone, and coal, which are unconformably overlain by Cretaceous shale and sandstone.

Hart River Formation. The oldest carbonates of the Lisburne Group in the southern assemblage occur in the upper Viséan to lower Serpukhovian Hart River Formation (Fig. 8.2; Bamber and Waterhouse, 1971). The formation, deposited in eastern Prophet Trough, lies chiefly in southern Eagle Plain, where it is up to 691 m thick (Pugh, 1983). It thins southwestward into the Ogilvie Mountains as it progrades over and passes laterally into basinal shale and siltstone of the upper Ford Lake Formation (Figs. 8.2, 8.8). Most of the Hart River is conformably overlain by the Blackie Formation, but north of the erosional zero edge of the latter, it is truncated below Lower Cretaceous strata.

Most of the Hart River Formation comprises thinly laminated, cherty spiculite and spicule lime packstone with subordinate sandstone, siltstone and calcareous shale (Fig. 8.15), but lime grainstone occurs locally in eastern outcrops. Thick, commonly sharp-based, lenticular to shoe string sandstone units grading into chert-rich conglomerate are also present (e.g., Chance Sandstone Member; Martin, 1972) in east-central Eagle Plain (Fig. 8.8). These units become less abundant and thin rapidly toward the south and west.

Graham (1973) demonstrated with seismic profiles that the carbonates and siliciclastics of the Hart River Formation prograded southwestward and were deposited in shelf, slope, and basin environments. The discontinuous sandstone and conglomerate units of east-central Eagle Plain are probably channel fills. Aggradation and regression are recorded by the presence of the terrigenous clastics and carbonate ramp deposits (Fig. 8.16) of the Hart River Formation above the shale-dominated Ford Lake Formation. The Hart River Formation and underlying transgressive Carboniferous lithofacies of the Ford Lake Formation jointly constitute a transgressive/regressive sequence.

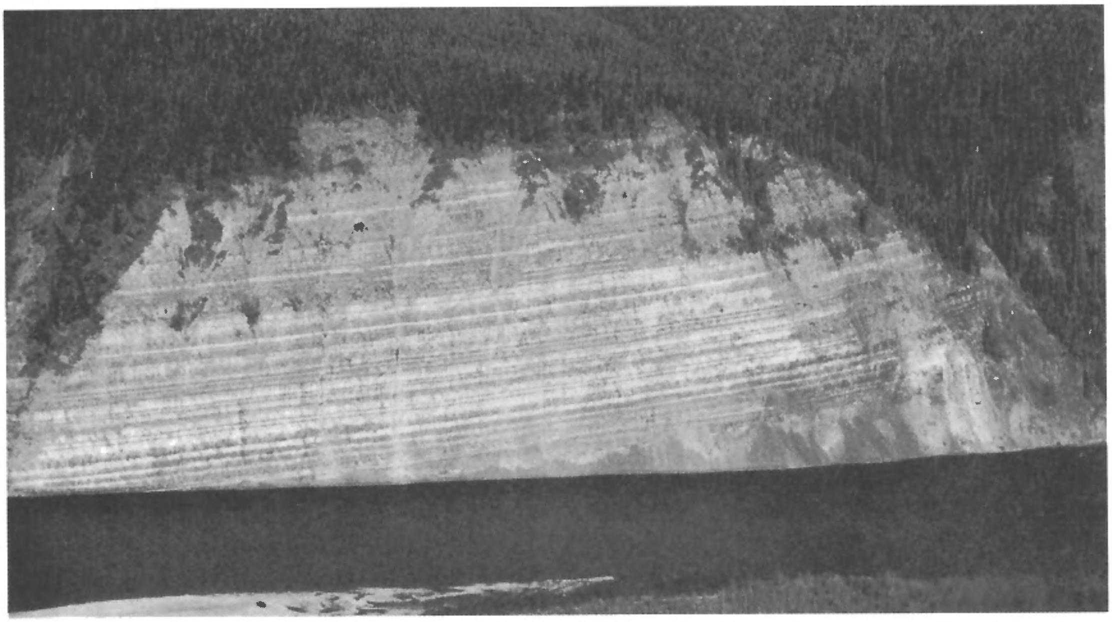


Figure 8.15. *Rhythmically bedded slope carbonates of the Hart River Formation, the north side of Peel River near the mouth of Hart River, southeastern Eagle Plain. ISPG photo 3407-7.*

Blackie Formation. Silicilastics and carbonates of the lower Serpukhovian to Kasimovian(?) Blackie Formation (Pugh, 1983) occur in southwestern Eagle Plain, the Keele Range, and the Ogilvie Mountains, where they overlie the Hart River Formation and attain a thickness of more than 700 m. The Blackie (Figs. 8.2, 8.8, 8.17), which generally underlies and grades northeastward into shelf carbonates of the Ettrain Formation, extends into northeastern Eagle Plain as a thinning tongue (unit 2 of Bamber and Waterhouse, 1971) that separates the Ettrain from the underlying Hart River. In the Ogilvie Mountains, southwest of the correlative Ettrain carbonates, the Blackie is overlain by the Jungle Creek Formation at a boundary that is mainly unconformable but may be locally conformable. North of the northern erosional zero edge of the Ettrain, the Blackie is truncated below Cretaceous strata.

In the southwest, the Blackie Formation comprises multiple hemicycles that become more resistant upward and consist of dark grey, calcareous shale and siltstone and silty, spiculitic limestone. Within the northeastern tongue, there are discontinuous bodies of sandy limestone and sandstone. The sandstone is chertarenite (Fig. 8.18) consisting of quartz (65–75%) and chert (25–35%); feldspar is rare. Thick, sharp based, fining-upward units of chert-pebble conglomerate and sandstone (Fig. 8.8) showing large scale, trough crossbedding are present in easternmost outcrops (Eagle Plain).

Most of the Blackie Formation was deposited under shallowing-upward conditions in basin to slope environments on a carbonate ramp and succeeding carbonate platform, as indicated by the low-energy deposits and regional lithofacies relationships. Transgressive shale and spiculitic ramp carbonates of the lower Blackie Formation onlap eastward and northward over the slope and shelf deposits of the Hart River Formation, recording an abrupt influx of terrigenous clastics and probable substantial deepening in the southwest during the Serpukhovian. Southwest of the correlative Ettrain shelf carbonates, upper Blackie platform lithofacies indicate that slope to basinal sedimentation continued until the Kasimovian(?).

Some conglomerate and sandstone units in the Blackie Formation of Eagle Plain are probably channel-fill deposits that had a northeastern provenance (Pugh, 1983). The environment in which the fill sequences developed has not been unequivocally determined, but a deltaic setting is probable. Their presence above the Hart River carbonates and basal transgressive shale of the Hart River Formation indicate a late Serpukhovian to Bashkirian regression. The regression probably resulted from a high rate of terrigenous influx caused by a major mid-Carboniferous drop in global sea level (Vail et al., 1977, fig. 1) and subsequent early Bashkirian lowstand. In the northern assemblage, the regression may be recorded by upper Serpukhovian deposits of the upper Alapah Formation.

Ettrain Formation. Bashkirian to Kasimovian(?) carbonates of the Ettrain Formation, more than 600 m thick in the southwest, cap the Carboniferous succession throughout much of the northern Ogilvie Mountains and Keele Range (Figs. 8.2, 8.8, 8.19, 8.20; Bamber and Waterhouse, 1971). They are also present in a narrow belt extending eastward across southern Eagle Plain (Pugh, 1983, fig. 21). The Ettrain thins southward and westward as it grades into the upper Blackie Formation. It also thins beneath the sub-Permian unconformity toward eastern Eagle Plain, where the youngest Ettrain strata are of Moscovian age. In the westernmost Ogilvie Mountains, Kasimovian(?) strata of the Ettrain Formation are overlain by sandstone, conglomerate, and shale of probable latest Carboniferous age (Kasimovian and Gzhelian) in the basal Jungle Creek Formation. The Ettrain/Jungle Creek contact may be locally conformable in this area (Figs. 8.2, 8.8). North of the northern erosional zero edge of the Jungle Creek Formation (Fig. 8.1, Permian zero edge), the Ettrain is truncated rapidly to zero below Cretaceous strata.

Ettrain carbonates are mainly cherty, echinoderm-bryozoan and ooid lime grainstone and mixed-skeletal lime packstone (Figs. 8.20, 8.21). Foraminifers, calcareous algae, and brachiopods are locally abundant. Quartz and chert sand and silt are generally present and become more abundant eastward, indicating continued terrigenous influx from the northeast. Glauconite is a conspicuous component in some sandy carbonates of the eastern Ettrain Formation.

The lithologic character and facies relationships (Bamber and Waterhouse, 1971) of the Ettrain suggest that it is dominantly a shallowing-upward succession deposited principally in protected shelf, shelf margin, and upper slope environments on a poorly differentiated carbonate platform (Fig. 8.16). In eastern outcrops of the Eagle Plain, near the western flank of the Richardson Mountains, unnamed correlatives of the upper Ettrain contain abundant silty dolostone and siltstone suggestive of protected to restricted shelf environments (Figs. 8.2, 8.8, 8.22). The Ettrain prograded westward and southward over the slope and basin deposits of the Blackie Formation.

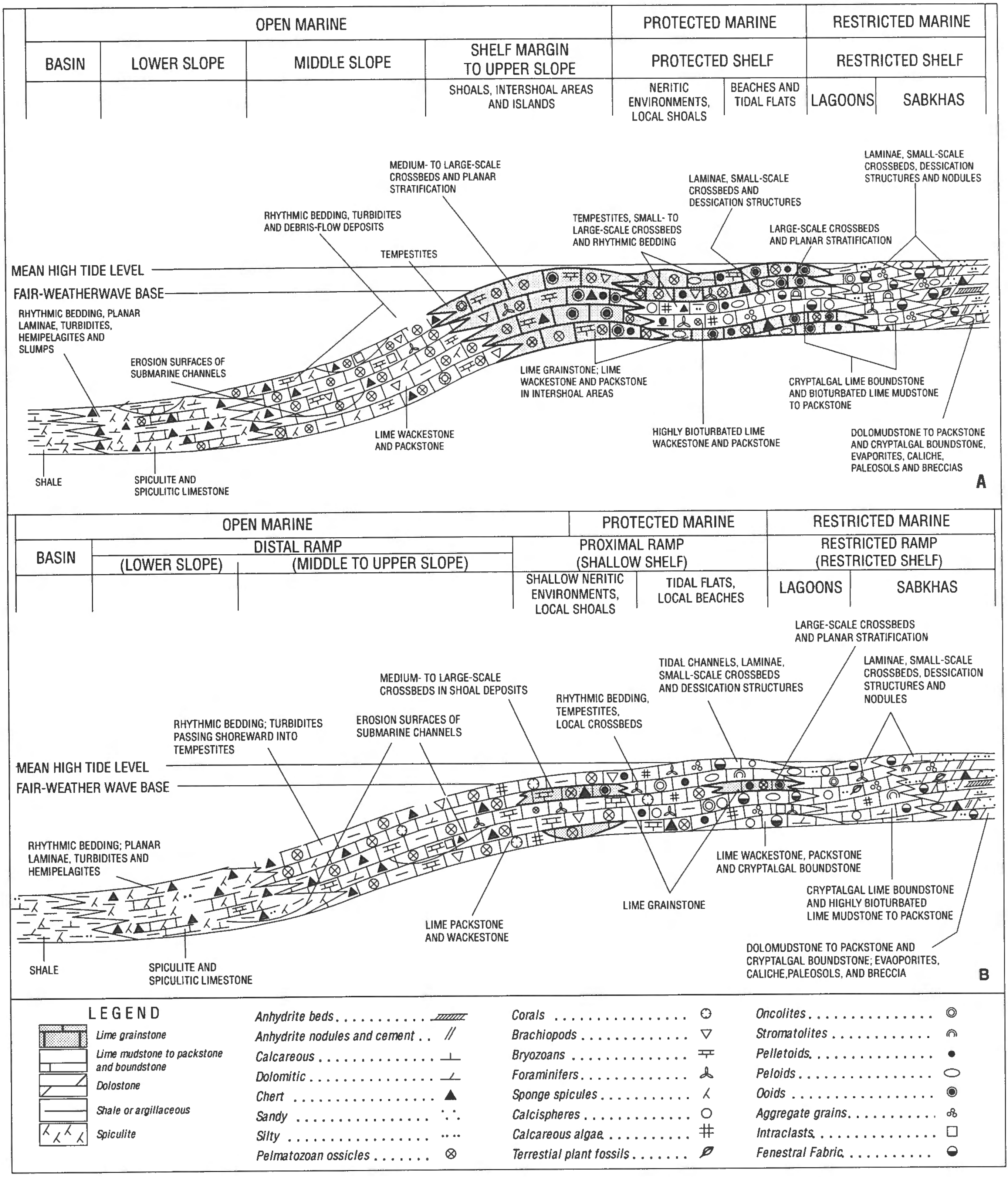


***Figure 8.16.** Generalized depositional models of a Carboniferous carbonate platform (A) and ramp (B) (from Richards, 1989).*

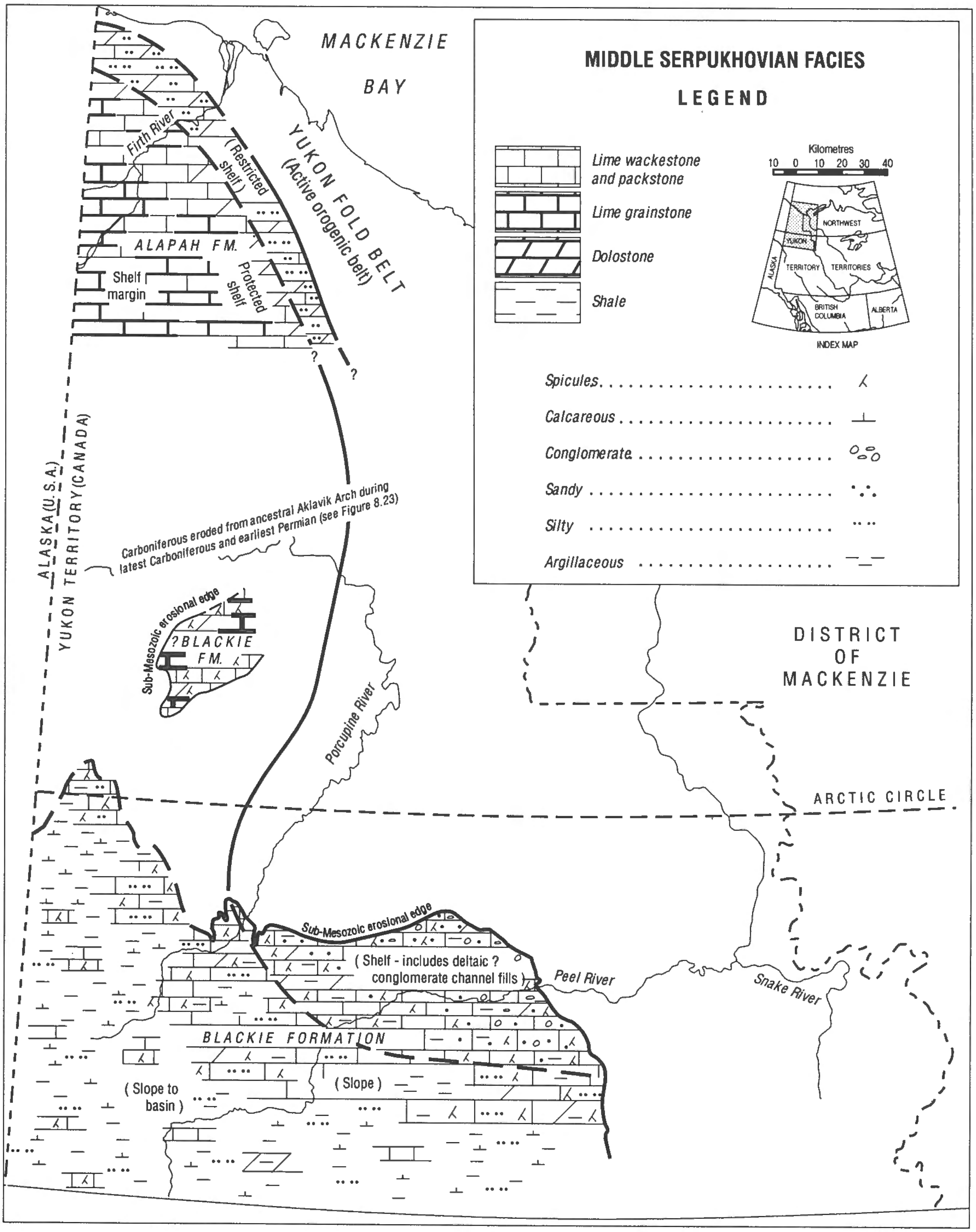


Figure 8.17. Generalized facies distribution map (middle Serpukhovian), lower Blackie Formation and middle and upper Alapah Formation (not palinspastically restored). See Figure 8.1 for the present-day distribution of Carboniferous deposits and Figure 8.2 for the stratigraphic level.

The Ettrain, a transgressive/regressive sequence in the east, records a transgression and the early phase of a subsequent regression, also recorded by correlative strata in the western Blackie Formation. In the east, the presence of the Ettrain and unnamed correlative marine carbonates above conglomerate channel fills and associated deltaic(?) siliciclastics of the Blackie Formation record a late Bashkirian to early Moscovian transgression. The early phase of a subsequent regression, caused in part by uplift of the Ancestral

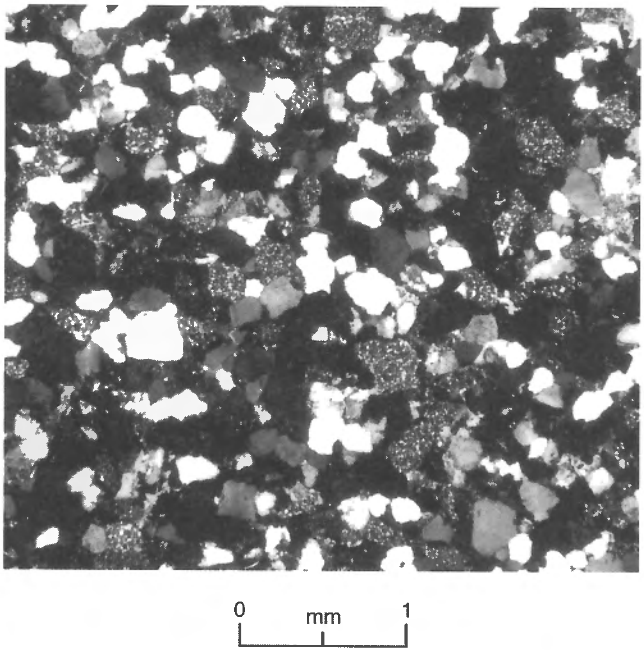


Figure 8.18. Photomicrograph of fine grained sandstone — slightly dolomitic submature chertarenite — from the eastern tongue of the Blackie Formation, Peel River, eastern Eagle Plain (GSC loc. C-70373). ISPG photo 3509-57.

Aklavik Arch, is recorded by the occurrence of sandy, protected to restricted marine carbonates in the upper part of the eastern Ettrain and its unnamed correlative farther east (Fig. 8.8). Regression culminated with subaerial erosion of the northeastern Ettrain and deposition of Kasimovian to Gzhelian conglomerate of the lowest Jungle Creek Formation to the southwest (Tatonduk River area of northern Ogilvie Mountains, Fig. 8.23).

Northern Assemblage. The northern assemblage of the upper Paleozoic succession consists of Tournaisian(?) to Moscovian carbonates and siliciclastics outcropping in the British and northern Richardson Mountains (Figs. 8.1, 8.2, 8.9, 8.24). This assemblage comprises parautochthonous deposits of the Endicott and Lisburne groups and extends onto the north slope and continental shelf of northern Alaska, where it is similar to that of Yukon in lithology and depositional origin (Wood and Armstrong, 1975; Armstrong and Mamet, 1977; Grantz et al., 1988). The northern assemblage, unconformably overlying deformed Precambrian to Devonian rocks, has basal beds ranging in age from Tournaisian(?) or early Viséan in the British Mountains to Moscovian in the northern Richardson Mountains. In the British Mountains, Tournaisian(?) and Viséan terrigenous clastics and subordinate carbonates of the Endicott Group (Kekiktuk and Kayak formations) constitute the lower part of the succession (Figs. 8.14, 8.24, 8.25). These lower strata are conformably overlain by carbonates of the Viséan to Bashkirian Lisburne Group (Alapah and Wahoo formations).

Kekiktuk Formation. The conglomerate-dominated Kekiktuk Formation (Brosgé et al., 1962) forms a poorly exposed, laterally discontinuous unit at the base of the northern succession (Figs. 8.2, 8.9, 8.14). It generally rests with angular unconformity on the lower Paleozoic (Lane and Cecile, 1989) and Proterozoic Neruokpuk Formation in the western and central British Mountains and on unnamed Ordovician and Silurian siliciclastics and chert in the Barn Range and at Hoidahl Dome to the east (D.K. Norris, 1981b, 1983, 1985). At Mount Sedgwick in the northern British Mountains, it rests nonconformably on Devonian granitic rocks. The Kekiktuk is generally less than 25 m thick and varies locally in thickness from less than 1 m to more than 50 m, with the thickest known deposits preserved at Hoidahl Dome southeast of the Barn Range. The Kekiktuk has not been precisely dated in Canada, but it is gradationally overlain by Viséan strata of the Kayak Formation and is, therefore, assumed to be of Early Carboniferous age. The boundary between the Kekiktuk and Kayak is placed at a level above which sandstone and shale become predominant and the succession becomes substantially less resistant.

The Kekiktuk comprises boulder-to-pebble conglomerate with subordinate conglomeratic sandstone (Figs. 8.25, 8.26) and minor shale. The coarse fraction is commonly angular to subangular and generally dominated by grey chert. Pebbles and cobbles of white vein quartz are common and locally predominate; clasts of grit, sandstone, and siltstone are moderately common. Scattered granitic pebbles to boulders, consisting mainly of quartz and sericitized feldspar, occur at Mount Sedgwick. Most sandstone in the unit is chertarenite and subchertarenite; quartzarenite is present in the upper Kekiktuk. Within the sandstone matrix of the conglomerate, metamorphic quartz that has an undulatory extinction of more than 5° is commonly more abundant than quartz with a straight extinction (<5°). Sand-sized clasts of plutonic quartz comprising more than three crystals are moderately abundant, but feldspar, heavy minerals, and mafic minerals are minor constituents in the sand fraction.

This formation, which fines upward overall, contains fining-upward units that resemble channel fills and display erosional bases. Rapid lateral facies changes, where conglomerate passes into sandstone, are common. Few primary sedimentary structures have been reported, but large-scale trough crossbedding is locally evident in some of the sharp-based units. Many beds show crude internal stratification and a clast-supported coarse fraction. Other beds are massive, and have a chaotic internal fabric and a sand-supported coarse fraction.

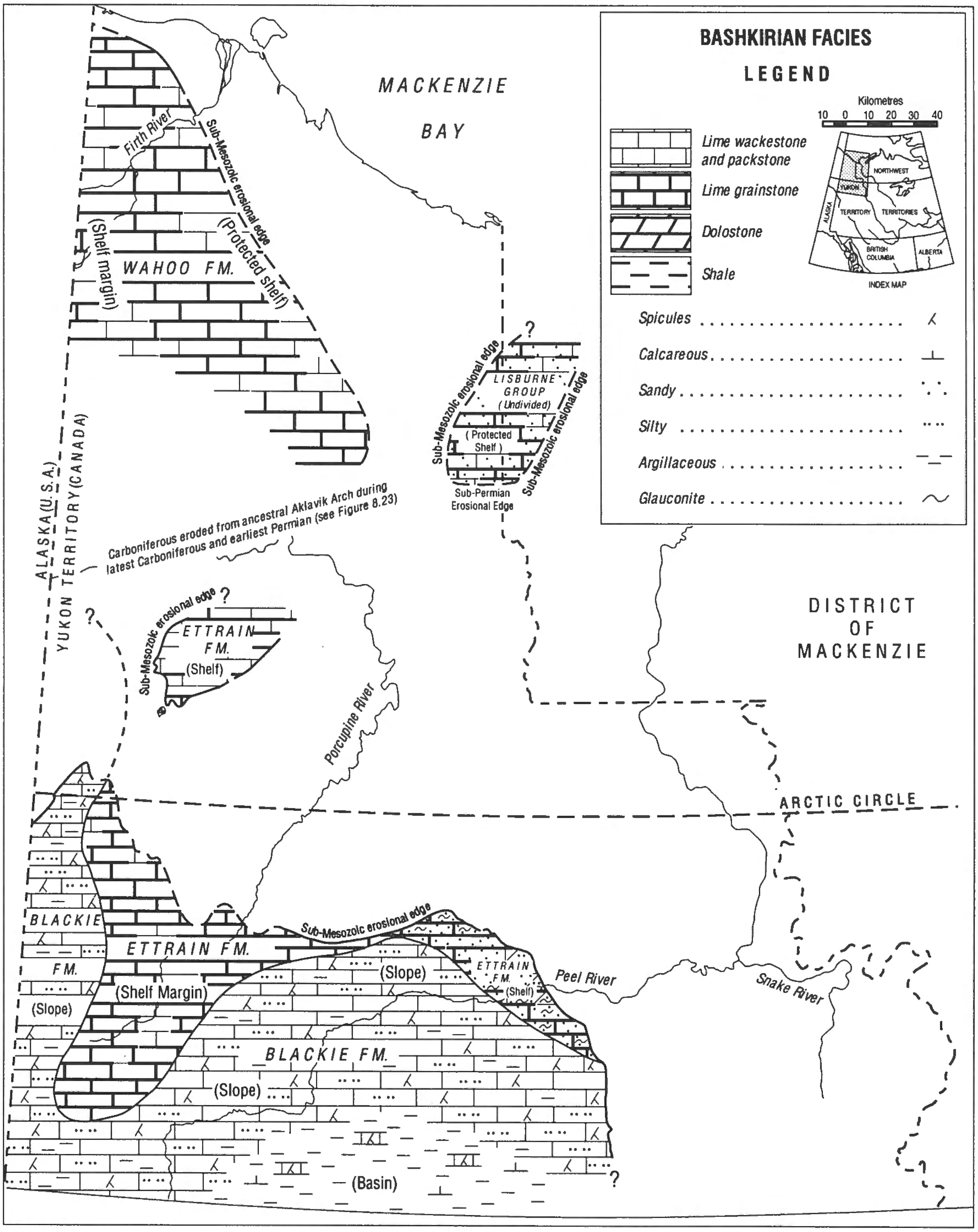


Figure 8.19. Generalized facies distribution map (Bashkirian), lower Ettrain Formation, middle to upper Blackie Formation, Wahoo Formation and Lisburne Group undivided (not palinspastically restored). See Figure 8.1 for the present-day distribution of Carboniferous deposits and Figure 8.2 for the stratigraphic level.

Figure 8.20. *Cliff-forming carbonates of the Ettrain Formation, lower part of the type section, between the heads of Ettrain and Jungle creeks, western Ogilvie Mountains, northern Yukon. The arrow indicates the base of the Ettrain (top not shown). The view is toward the northwest. GSC photo 114811.*

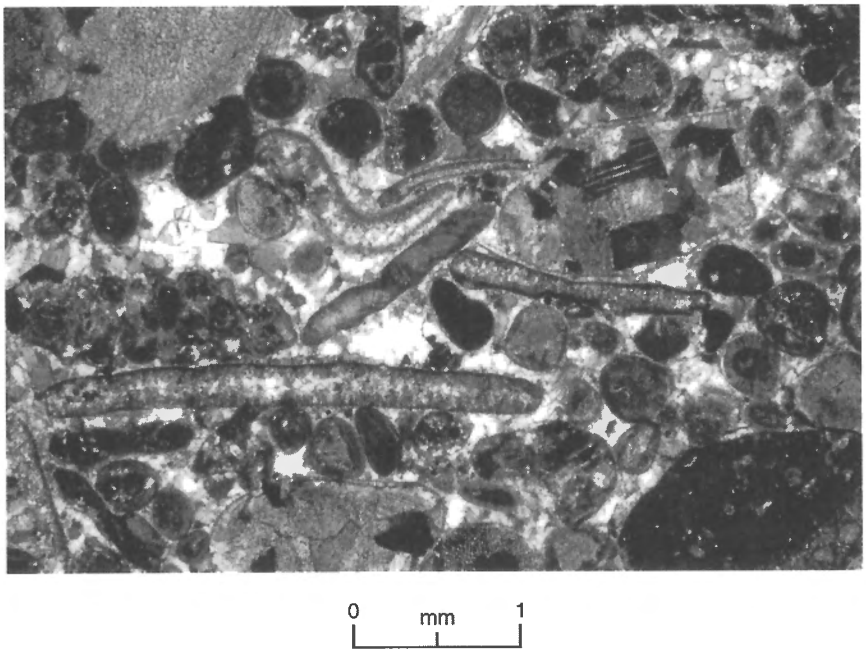


Figure 8.21. *Photomicrograph of ooid-skeletal lime grainstone from the type section of the Upper Carboniferous Ettrain Formation in western Ogilvie Mountains. Principal bioclasts are: ramose bryozoans, molluscs, pelmatozoan ossicles, foraminifers and phylloid algae. Ooids, and carbonate intraclasts are common (GSC loc. C–2746). ISPG photo 3509–68.*

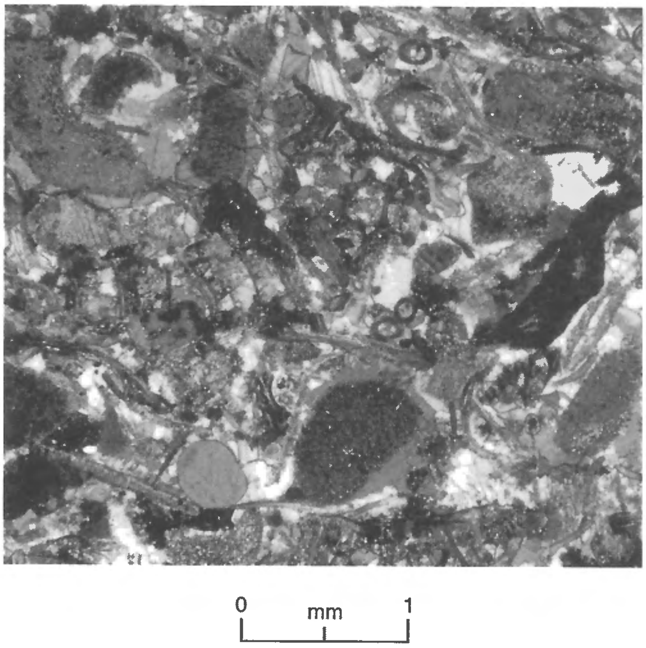


Figure 8.22. Photomicrograph of slightly glauconitic, bryozoan-brachiopod-pelmatozoan lime grainstone from an eastern unnamed correlative of the Ettrain Formation on Peel River, southeastern Eagle Plain (GSC loc. C-70370). ISPG photo 3509-73.

The characteristics and regional relationships of the Kekiktuk suggest deposition in braided stream and alluvial fan to fan delta settings landward of finer grained coastal plain and marine lithofacies partly preserved in the Kayak Formation (Fig. 8.9). Deposition in a dominantly continental environment is indicated by the stratigraphic position of the formation between an underlying subaerial erosion surface and an overlying succession of coal-bearing coastal plain lithofacies (Kayak Formation). Terrestrial deposition is also suggested by the absence of marine fossils in most of the unit. Shale beds in lithofacies transitional to the overlying Kayak Formation locally contain scolecodonts; they are, therefore, at least partly of marine origin. A braided stream/fan delta setting is suggested by the texturally immature, locally derived sediments and the presence of conglomerate channel fills. Rapid lateral thickness changes in the Kekiktuk of the study area probably resulted from the filling of valleys (possibly of block fault origin) during the initial onlap of the Yukon Fold Belt.

In Alaska, braided stream deposits constitute most of the lower and middle Kekiktuk, whereas meandering stream deposits predominate in the upper part (Nilsen, 1981). Bloch et al. (1990, p. 1374) recognized that most of the fluvial facies in Alaska are preserved in fan delta systems that prograded southwestward.

Lithofacies of the Kekiktuk probably represent depositional systems that developed landward of delta and prodelta environments represented by the Tuttle and Ford Lake formations of the southern assemblage and the Kanayute Conglomerate in Alaska (Figs. 8.2, 8.4). However, the paleogeographic relationships between the environments represented by these four formations have been obscured by latest Carboniferous and subsequent erosion and tectonism.

Kayak Formation. In the study area, middle(?) and upper Viséan siliciclastics and subordinate carbonates of the Kayak Formation (Figs. 8.2, 8.9, 8.14, 8.24, 8.25; Bowsher and Dutro, 1957) are preserved mainly in the Barn Range and British Mountains (Bamber and Waterhouse, 1971, p. 72-73). Strata mapped as the Kayak Formation are also preserved at Hoidahl Dome and in the northern Old Crow Plain (D.K. Norris, 1981b, 1985; Morrell and Dietrich, 1993). In Alaska, the Kayak is widely preserved in the Brooks Range and on the north slope and continental shelf (Nilsen, 1981; Mull et al., 1987). In most of Yukon, the Kayak gradationally overlies the Kekiktuk Formation, but where the latter is not developed, it rests with angular unconformity on the highly deformed lower Paleozoic and Proterozoic Neruokpuk Formation (D.K. Norris, 1981b; Lane and Cecile, 1989). Data from palynomorphs suggest the basal Kayak is of late Tournaisian to early Viséan age in Yukon.

In the western part of the study area, the thickness of the Kayak Formation ranges from 220 m near Trout Lake, northwest of the Barn Range, to about 335 m near the Alaska border. The maximum known thickness of approximately 375 m occurs in the Barn Range (Bamber and Waterhouse, 1971, p. 74).

Carbonates of the Viséan and Serpukhovian Alapah Formation overlie the Kayak in most of the British Mountains and adjacent areas. The boundary between these two units is partly conformable and diachronous, becoming younger northeastward. In the northeastern British Mountains, the contact is at least locally erosional where sandstone of the Kayak is abruptly overlain by transgressive carbonates of the basal Alapah (Figs. 8.9, 8.25). In the Barn Range, northeast of the erosional zero edge of the Alapah, the Kayak is truncated northeastward below Triassic and Jurassic strata.

In most of the study area, the Kayak comprises a basal sandstone-bearing unit, a middle shale-dominated unit, and an upper interval of shale and subordinate limestone (Fig. 8.9; Bamber and Waterhouse, 1971, p. 74-75). In the northeastern

British Mountains, however, sandstone is common in the middle and upper Kayak Formation (Figs. 8.9, 8.25). The thicknesses of these subdivisions are not well documented because of poor exposure.

The basal unit comprises dark grey to black shale and siltstone with subordinate thin bedded sandstone (quartzarenite and subordinate subchertarenite). Thin conglomerate beds and conglomeratic sandstone are

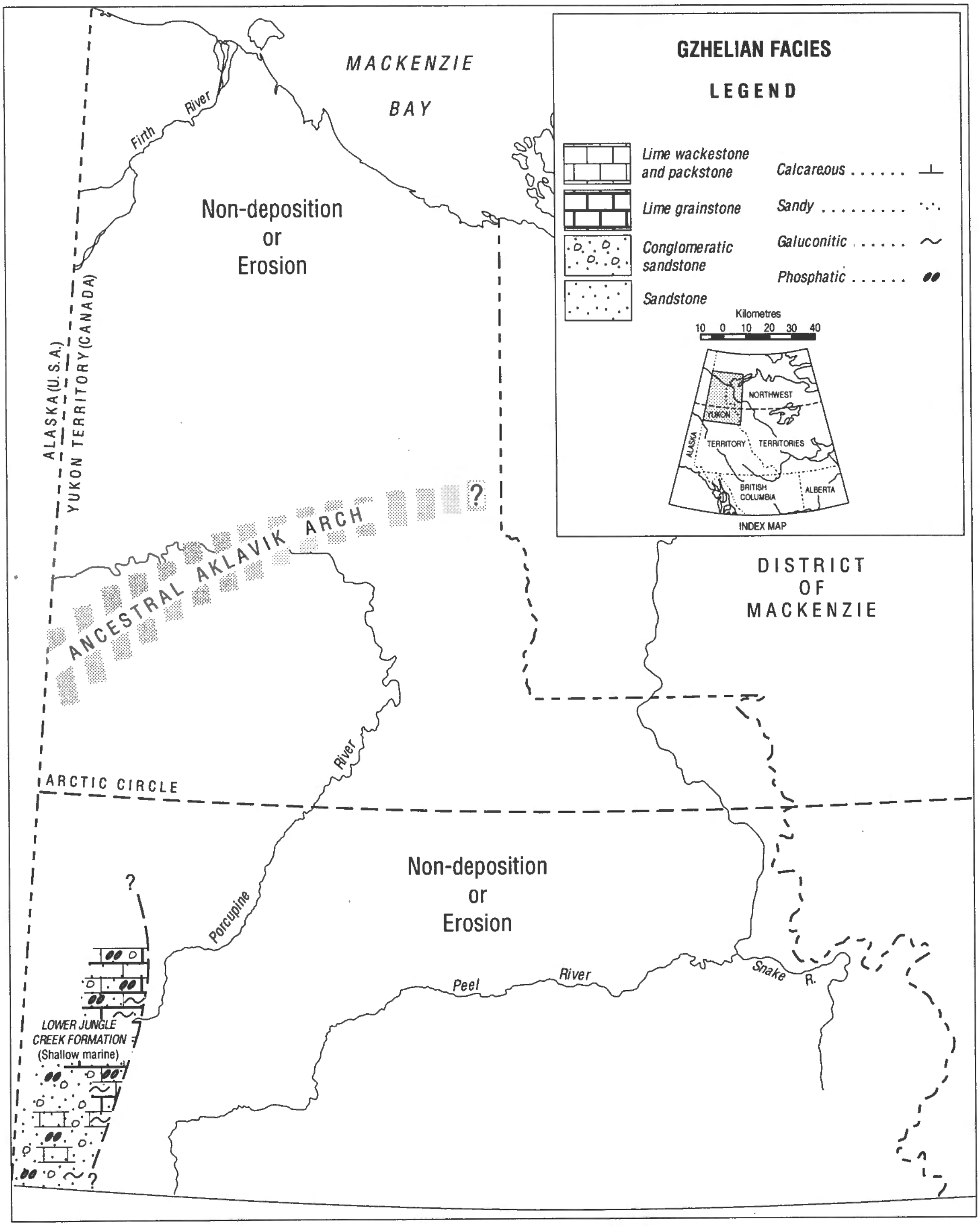


Figure 8.23. Generalized facies distribution map (Gzhelian), lowest Jungle Creek Formation. The map shows the approximate extent of the Ancestral Aklavik Arch (not palinspastically restored). See Figure 8.1 for the present-day distribution of Carboniferous deposits and Figure 8.2 for the stratigraphic level.

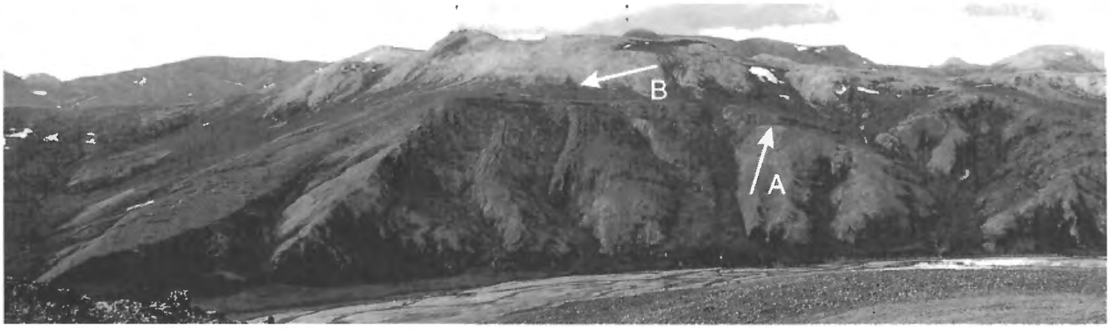


Figure 8.24. *Carboniferous rocks in the British Mountains. Arrow A indicates the base of the Endicott Group (Kekiktuk and Kayak formations), which rests with angular unconformity on steeply dipping strata of the Precambrian and lower Paleozoic Neruokpuk Formation. Arrow B indicates the base of the Lisburne Group (carbonates of Alapah and Wahoo formations). The view is to the northwest across Malcolm River. GSC photo 662–51.*

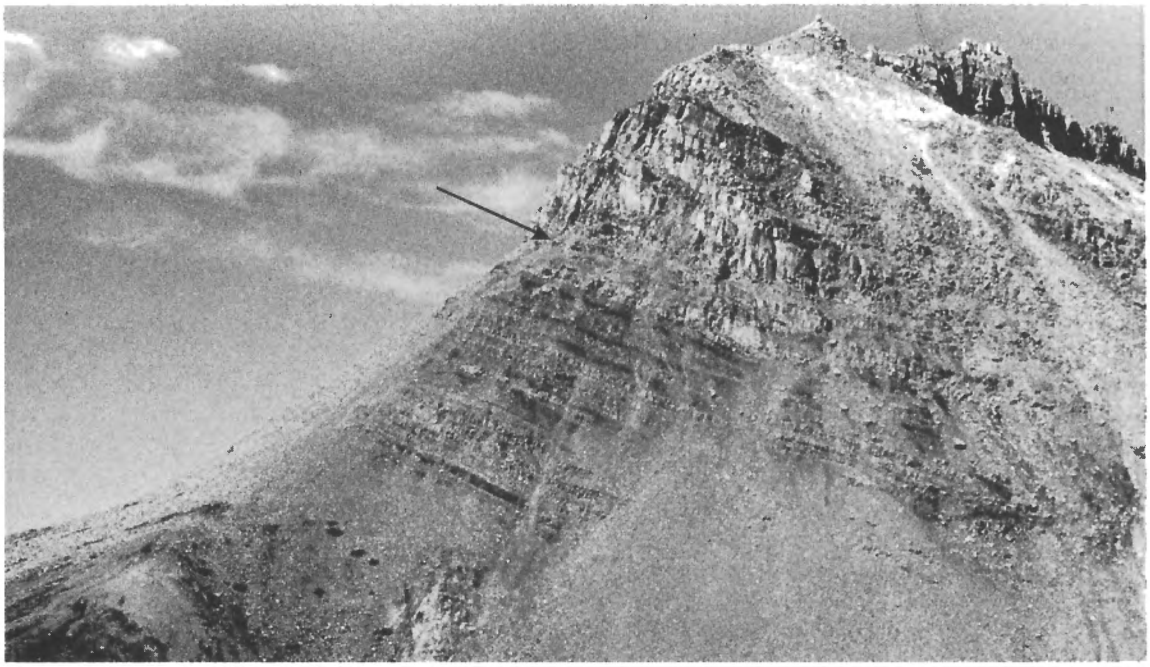


Figure 8.25. *The middle and upper Kayak Formation (Viséan), abruptly overlain by upper Viséan and Serpukhovian platform carbonates of the lower Alapah Formation (arrow indicates base), near the head of Crow River, northern British Mountains, Yukon. The middle Kayak comprises marine shale passing upward into interbedded deltaic shale and sandstone of the upper Kayak. ISPG photo 3469–1.*

preserved locally. Macroscopic, terrestrial plant remains are generally common in the sandstone and shale. Coal seams, which are generally thin but range up to 5.5 m in thickness at Hoidahl Dome (Cameron et al., 1986), are commonly present.

The lower sandstone and shale unit grades upward and westward into dark grey, calcareous shale and minor argillaceous, silty, mixed-skeletal lime packstone and wackestone of the middle division (Figs. 8.9, 8.28). In the central and western British Mountains, the proportion of limestone increases upward, thereby forming the upper package.

Shale and limestone of the middle and upper Kayak Formation pass northeastward into shale, carbonaceous sandstone, and coal, outcropping in the northeastern British Mountains (Fig. 8.25; Bamber and

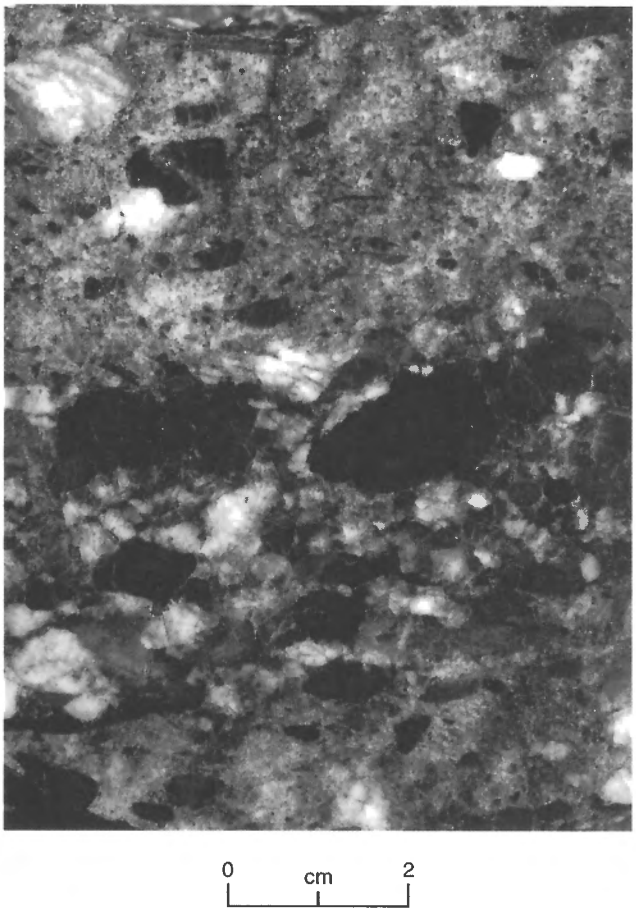


Figure 8.26. A polished slab of conglomerate grading into conglomeratic sandstone from the Tournaisian to Viséan Kekiktuk Formation on Bear Creek, northern British Mountains (GSC loc. C–138635). The granule and pebble fraction is dominated by clasts of chert and white vein quartz. ISPG photo 3509–53. See Figure 8.27 for a photomicrograph of the matrix.

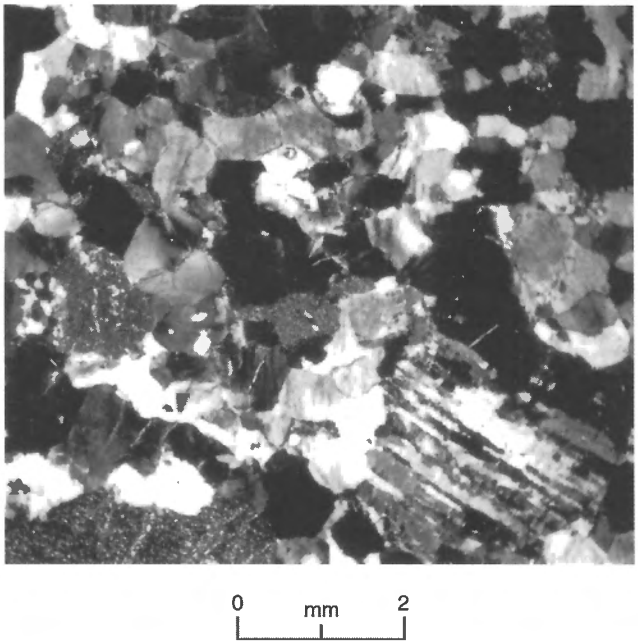


Figure 8.27. A photomicrograph of conglomeratic, coarse sandstone — siliceous, submature subchertarenite — from the Kekituk sample illustrated in Figure 8.26. The sandstone is dominated by clasts of metamorphic quartz showing well developed undulatory extinction. ISPG photo 3509–85.

Waterhouse, 1971). In the latter area, sharp-based channel fills grading upward into shale are common in the sandstone-dominated upper part of the formation.

Throughout most of the British Mountains, the Kayak is a transgressive, deepening-upward succession similar to that in the Brooks Range of Alaska (Nilsen, 1981). Regional lithofacies trends indicate that the diachronous, onlapping, coal-bearing siliciclastics of the basal Kayak were deposited in shoreline and coastal plain environments that succeeded the fluvial to deltaic(?) environments represented by the underlying Kekiktuk Formation. Kayak shale and carbonates occurring above and west of the basal and eastern siliciclastic facies were probably deposited in shallow neritic (above storm wave base) to intertidal environments. The latter lay on the landward or lagoonal side of a protected shelf on which coeval carbonates of the lower Alapah Formation were accumulating.

Channel fills in the sandstone-dominated upper Kayak of the northeastern British Mountains record late Viséan delta development and regression. The latter may have resulted from regional, late Viséan blockfaulting in the Ellesmerian Fold Belt to the northeast (Beauchamp et al., 1989a, b).

The Kayak and underlying Kekituk Formation jointly record a transition from deposition in terrigenous systems to sedimentation in carbonate-dominated systems. They also constitute the lower part of a transgressive/regressive sequence that includes the Alapah Formation.

Alapah Formation. The middle Viséan to upper Serpukhovian Alapah Formation (Figs. 8.2, 8.9, 8.17, 8.25; Bowsher and Dutro, 1957) is the thickest, most extensively preserved Carboniferous carbonate unit of northern Yukon. It lies mainly in the British Mountains, where it extends southeastward from the Alaska border to the Barn Range and southward from the Arctic coastal plain to the Old Crow Plain. This

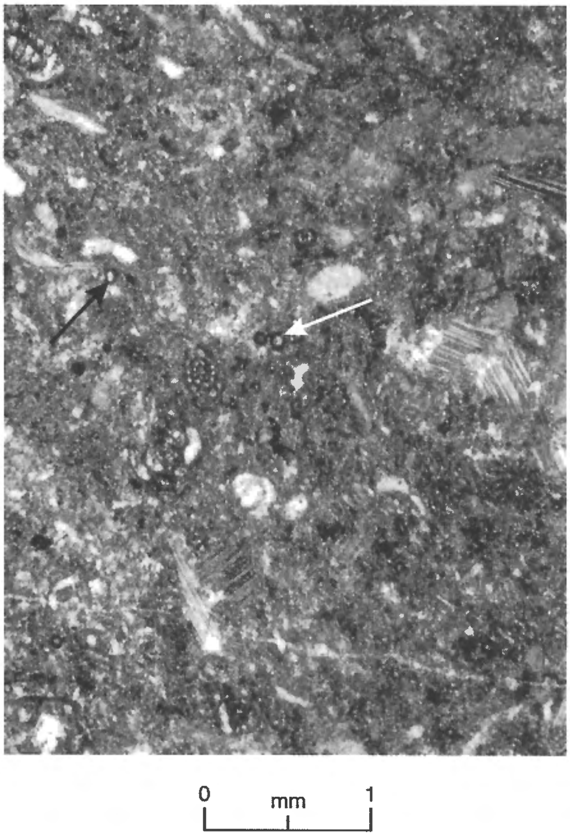


Figure 8.28. *A photomicrograph of middle to upper Viséan, mixed-skeletal lime wackestone from the upper Kayak Formation near Joe Creek (lat. 68°54′N, long. 140°52′W), southern British Mountains, near the Alaska border. The sample contains calcispheres (arrows), foraminifers, pelmatozoan ossicles, and brachiopods (GSC loc. C–190384). ISPG photo 3509–71.*

poorly exposed formation is also widely preserved along the northeastern and eastern margins of the Old Crow Plain and occurs locally as erosional remnants in grabens on the north flank of the Ancestral Aklavik Arch. In Alaska, Alapah carbonates are widely preserved in the Brooks Range and on the north slope (Wood and Armstrong, 1975; Armstrong and Mamet, 1975, 1978). The Alapah is more than 1300 m thick in the western British Mountains and thins northeastward. Its thickness and lithological character in the Barn Range have not been determined (Bamber and Waterhouse, 1971).

In most of the study area, the Alapah overlies the Kayak Formation at a contact that is conformable and diachronous in the southwest but locally erosional in the northeast. Near Bonnet Lake, south of Hoidahl Dome, the Alapah unconformably overlies lower Paleozoic strata (Norris, 1981b).

Carbonates of the Wahoo Formation overlie the Alapah in most of the region. The sharp Alapah/Wahoo boundary, which coincides with the mid-Carboniferous boundary as proposed by Lane et al. (1985), has not been carefully studied and may be a minor unconformity. North and east of the sub-Mesozoic erosional edge of the Wahoo, Mesozoic strata unconformably overlie and truncate the Alapah.

In the British Mountains, the lower Alapah Formation is mainly lime mudstone and wackestone containing abundant calcareous algae (Fig. 8.9). Mixed-skeletal lime packstone and grainstone containing numerous echinoderm fragments, bryozoans, and foraminifers dominate the upper part (Fig. 8.29). Grainstone is particularly abundant in the southwest. In the northern and northeastern British Mountains, the Alapah contains abundant, finely crystalline, sandy to silty dolostone and calcareous algae; sandstone and shale are present as well. Stromatolites, laminated algal-mat dolostone, and cryptalgal laminites with birdseye structures are locally well developed in northeastern Alaska (Wood and Armstrong, 1975; Armstrong and Mamet, 1975, p. 4) and occur in the northern British Mountains of the study area (Bamber and Waterhouse, 1971, p. 81). Medium-scale crossbedding is common in the sandy to

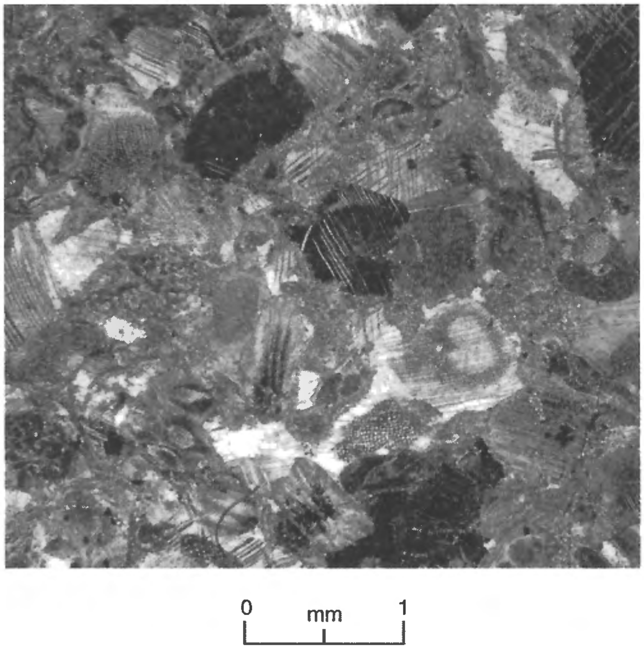


Figure 8.29. *A photomicrograph of lower Serpukhovian, bryozoan-pelmatozoan lime grainstone from upper Alapah Formation near Joe Creek (lat. 68°54′N, long. 140°52′W), southern British Mountains, near the Alaska border (GSC loc. C–190359). ISPG photo 3509–79.*

silty carbonates, but crossbedding has not been reported in other rock types.

Lithofacies relationships within the Alapah suggest that the lower and northeastern parts of the formation were deposited in restricted to protected shelf environments, with shelf margin environments developing to the southwest during deposition of the upper Alapah (Fig. 8.9).

The presence of the Alapah above the Kayak and lower Paleozoic strata in northern Yukon and Alaska records a regional transgression and onlap of shallow marine carbonates. Erosional breaks lying within the formation and at its base suggest that this transgression was interrupted by minor regressions. Carbonates of the uppermost Alapah may record a regression resulting from the major mid-Carboniferous drop in global sea level.

Wahoo Formation. The northern Carboniferous assemblage is capped with Bashkirian limestone of the Wahoo Formation (Figs. 8.2, 8.9, 8.19; Brosgé et al., 1962). This unit is poorly exposed in northern Yukon but is well exposed in northeastern Alaska (Wood and Armstrong, 1975; Armstrong and Mamet, 1975). In the study area, the Wahoo occupies approximately the same region as the underlying Alapah Formation but is slightly less widely distributed because of post-Bashkirian subaerial erosion. In most areas, Wahoo carbonates, which conformably(?) overlie the Alapah Formation, are disconformably overlain by siliclastics and carbonates of the Lower Permian Sadlerochit Formation. North and northeast of the Sadlerochit erosional edge, Mesozoic strata unconformably overlie and truncate the Wahoo. The Wahoo ranges in thickness from approximately 130 to 225 m in the central and western British Mountains.

Throughout most of the British Mountains, the Wahoo Formation is a cyclic succession dominated by lime grainstone and packstone rich in echinoderm, bryozoan, and brachiopod fragments. Foraminifers, including locally abundant fusulinaceans, occur throughout, and peloids and calcispheres are locally abundant. Ooid and skeletal-ooid grainstone dominate the upper Wahoo in the northwest (Fig. 8.30). In the Barn Range, the Wahoo contains skeletal grainstone and packstone of unknown thickness (Bamber and Waterhouse, 1971).

Wahoo carbonate lithofacies suggest deposition in protected shelf to shelf margin environments on a poorly differentiated platform (Fig. 8.16) with little terrigenous influx. A Bashkirian regional transgression is recorded by the presence of the Wahoo above sandy, restricted marine lithofacies of the Alapah in the northern and northeastern British Mountains. It is also recorded by the Wahoo of northeastern Alaska (Wood and Armstrong, 1975, p. 11).

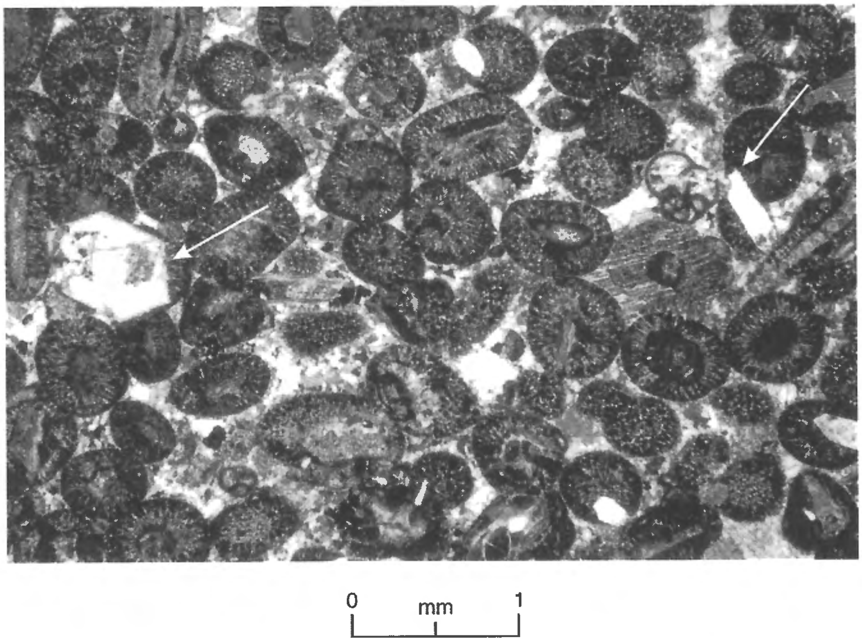


Figure 8.30. *A photomicrograph of ooid lime grainstone from the Bashkirian Wahoo Formation, western British Mountains. Authigenic quartz (arrows) is moderately abundant (GSC loc. C–70585). ISPG photo 3509–59.*

Undivided Lisburne Group of northern Richardson Mountains. East of the Barn Range, in the southern part of Rapid Depression (D.K. Norris, 1983), the Lisburne Group was removed by regional erosion prior to Jurassic deposition (Fig. 8.9). Farther east, in the northern Richardson Mountains (northwestern District of Mackenzie), the Carboniferous comprises Bashkirian to Moscovian shelf carbonates and subordinate sandstone of the Lisburne Group (undivided; Fig. 8.2). These deposits, which resemble those of the Lisburne to the west, conformably overlie an unnamed Upper Carboniferous sandstone unit, which in turn unconformably overlies the Lower to Middle? Devonian Ogilvie Formation (Nassichuk and Bamber, 1978). The Lisburne and underlying sandstone constitute the most easterly part of the onlapping, northern Carboniferous succession. They occur as erosional remnants beneath the sub-Permian disconformity on the north flank of the Ancestral Aklavik Arch, and are truncated eastward toward the Interior Platform and southward toward the axis of Ancestral Aklavik Arch.

In the northern Richardson Mountains, the preservation of Lisburne carbonates above unnamed Upper Carboniferous sandstone records the late phase of the transgression, represented by the Wahoo Formation. In the Sverdrup Basin to the northeast, a regional Bashkirian to middle Moscovian transgression, resulting largely from rifting during the opening of the basin, is recorded by the Canyon Fiord Formation and its correlatives (Beauchamp et al., 1989a, b).

Permian

Stratigraphic framework and unconformities. Permian rocks of the study area are preserved in the Ogilvie Mountains, the Keele Range, southern Eagle Plain, the northern Richardson Mountains, and the British Mountains (Figs. 8.1, 8.3, 8.31–8.35). They consist of Asselian to Wordian marine siliciclastics and carbonates that were deposited principally in northern

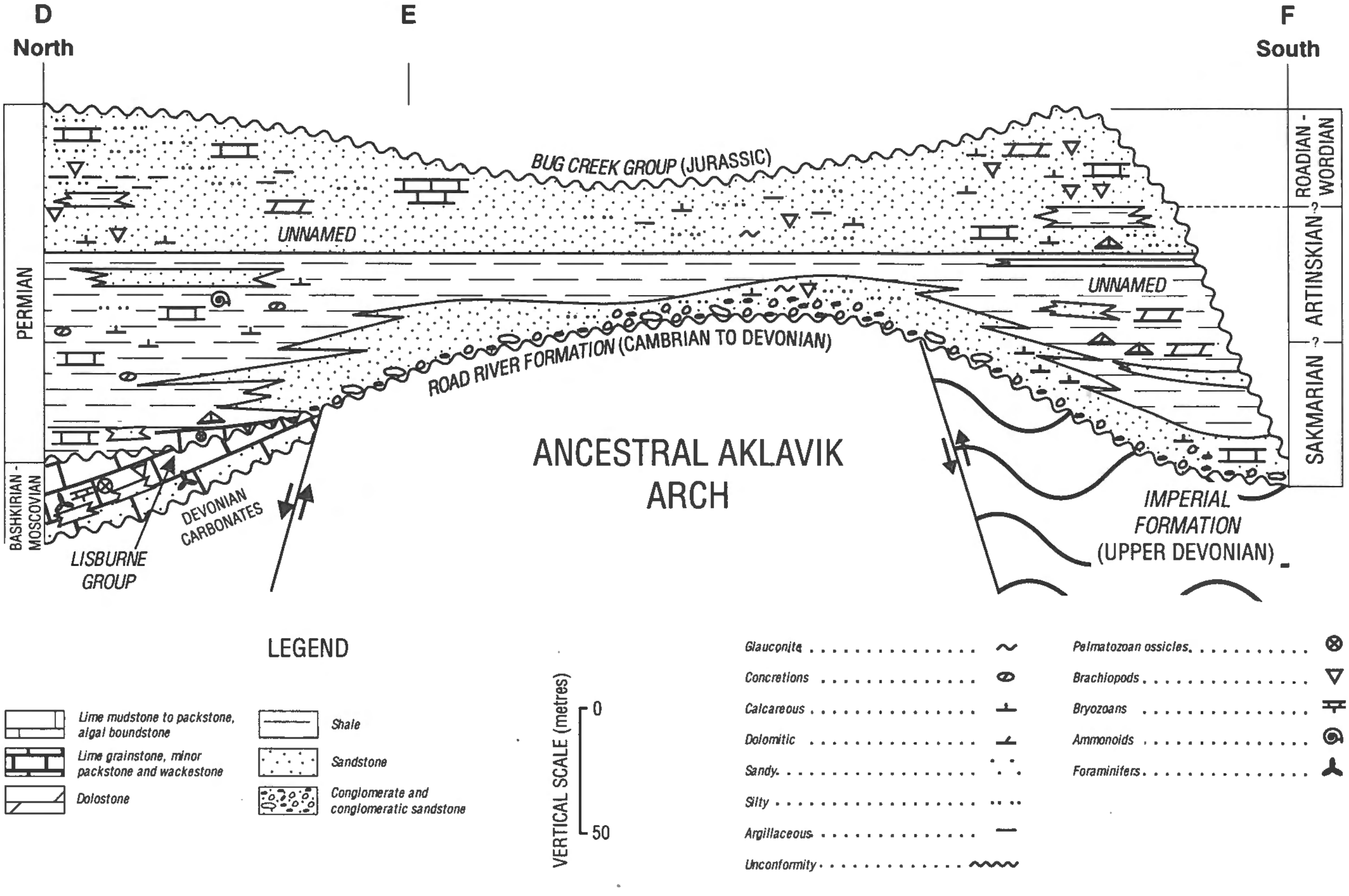


Figure 8.31. *Schematic stratigraphic cross-section D–E–F showing an unnamed Permian succession of northern Richardson Mountains (after Henderson et al., 1993). See Figure 8.1 for the line of section.*

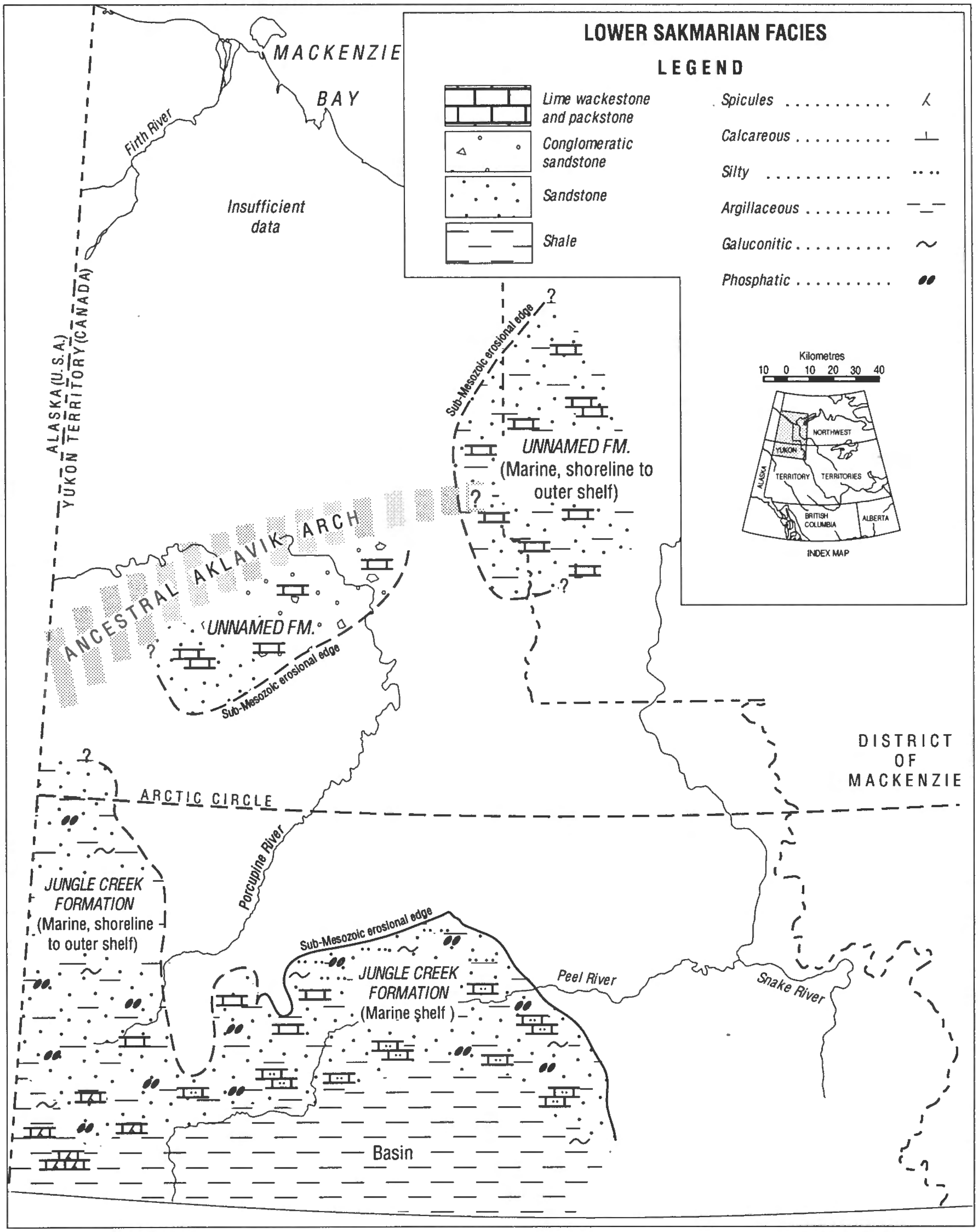


Figure 8.32. *Generalized facies distribution map (lower Sakmarian), lower Jungle Creek Formation, and unnamed carbonate and sandstone unit of northern Richardson Mountains. The map shows the approximate extent of Ancestral Aklavik Arch (not palinspastically restored). See Figure 8.1 for the present-day distribution of Permian deposits and Figure 8.3 for the stratigraphic level.*

Ishbel Trough and in an unnamed basin to the north. The Permian facies belts trend northeastward, approximately at right angles to those of the underlying Carboniferous (Bamber and Waterhouse, 1971).

Permian facies relationships adjacent to the Ancestral Aklavik Arch are best illustrated in the northern Richardson Mountains (Fig. 8.31), where a thick (up to 1500 m), unnamed succession of

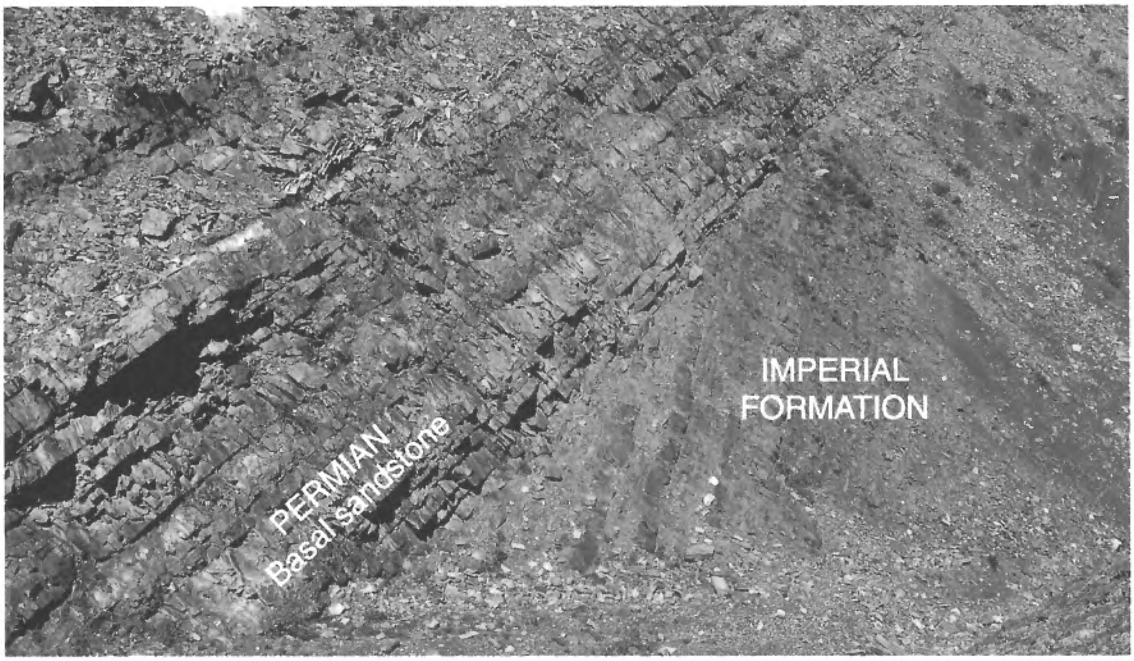


Figure 8.33. *Permian siliciclastics near McDougall Pass, northern Richardson Mountains (lat. 67°40′ N, long. 136°20′ W). Unnamed basal sandstone and conglomerate rest with angular unconformity on the Upper Devonian Imperial Formation. GSC photo 114792.*

terrigenous clastics and minor carbonates unconformably overlies Upper Carboniferous and older rocks. On the south flank of the arch, this unnamed succession is also preserved in the eastern Keele Range (D.K. Norris, 1981b, d, e, 1985).

In the northern Ogilvie Mountains near the Yukon/Alaska border, a thick, varied assemblage of Asselian to Wordian siliciclastics, carbonates, and chert is present on the south flank of the Ancestral Aklavik Arch (Fig. 8.35). This succession, also exposed in east-central Alaska (Brabb and Grant, 1971), was divided by Bamber and Waterhouse (1971) into the Jungle Creek Formation and overlying Tahkandit Formation. The lower part of this southern succession is also widely exposed in the eastern Ogilvie Mountains and underlies southern Eagle Plain. The Step Formation (Step Conglomerate), established in adjacent Alaska by Brabb (1969), is present in the westernmost part of the area (D.K. Norris, 1981g, 1985).

In the western British Mountains, the Permian Sadlerochit Group of Leffingwell (1919) occurs mainly as thin erosional remnants between the Carboniferous and Mesozoic deposits. Correlative deposits are widely preserved in the Permian to Triassic Sadlerochit Group of northern Alaska (Detterman et al., 1975).

A regional subaerial unconformity separates the Permian from Moscovian and older strata throughout most of the study area (Figs. 8.3, 8.33; Norris, 1983). This hiatus, present throughout the Western Canada Sedimentary Basin (Richards et al., 1993) and northern Alaska, resulted from Kasimovian to early Permian subaerial erosion caused by uplift of Ancestral Aklavik Arch and latest Carboniferous low global sea levels (Vail et al., 1977; Veevers and Powell, 1987). The same regression and episode of erosion have been recorded in the Sverdrup Basin northeast of the study area (Beauchamp et al., 1989b). As previously stated, erosion was greatest along the axis of Ancestral Aklavik Arch, where the Permian overlies mainly lower Paleozoic and older rocks. The base of the Permian in the northern Ogilvie Mountains becomes younger and rests on progressively older units toward the axis of the arch, as it does in the northern Richardson Mountains. Deposition may have been locally continuous across the Carboniferous/Permian boundary in the westernmost Ogilvie Mountains (Figs. 8.2, 8.35).

Regional unconformities occur within most Permian successions elsewhere in western and northern Canada (Henderson, 1989; Henderson et al., 1993; Beauchamp et al., 1989b) and are probably present within the study area but have not been recognized. A local break lies between the Jungle Creek and Tahkandit formations (Figs. 8.3, 8.35). Toward the northwest, the magnitude of this hiatus increases rapidly, and in east-central Alaska, the sub-Tahkandit break merges with the main sub-Permian unconformity. There, the Tahkandit and

Figure 8.34. *An unnamed Permian siliciclastic succession near McDougall Pass, northern Richardson Mountains (lat. 67°41′N, long. 136°20′W). The succession shows a basal sandstone and conglomerate unit, a middle shale unit, and an upper sandstone unit. The view is toward the north. GSC photo 114795.*

correlative Step Conglomerate unconformably overlie Precambrian to upper Paleozoic strata near the axis of the Ancestral Aklavik Arch (Brosgé and Dutro, 1973, p. 370; Brabb and Grant, 1971). The sub-Tahkandit unconformity possibly resulted from Artinskian to Roadian uplift of Ancestral Aklavik Arch, a site of recurrent tectonism. It may also have resulted partly from the major middle Artinskian drop in global sea level (Vail et al., 1977, fig. 1). The latter event, which produced a regional subaerial unconformity in the Western Canada Sedimentary Basin south of the study area (Henderson et al., 1993), has not been unequivocally documented in the study area.

Regional subaerial unconformities separate the Permian from Triassic to Upper Cretaceous strata (D.K. Norris, 1983), with the result that no Permian rocks younger than Wordian are preserved. Extremely low, Late Permian (post-Wordian) global sea levels (Vail et al., 1977, fig. 1) are interpreted to have been the principal cause of the sub-Triassic erosional break in the British Mountains. The Permian–Jurassic hiatus in the British and Ogilvie mountains and on the Aklavik Arch complex resulted largely from uplift caused by an early phase of the opening of Canada Basin. In northern Eagle Plain, Permian strata are absent as a result of truncation beneath regional sub-Jurassic and Cretaceous unconformities (Pugh, 1983, fig. 22). Broad upwarping accompanied by subaerial erosion during the Columbian phase of the Laramide Orogeny produced the latter break.

Unnamed Permian of northern Richardson Mountains and eastern Keele Range. In the northern Richardson Mountains, the unnamed Permian succession unconformably overlies lower Paleozoic deposits and erosional remnants of Carboniferous units preserved partly in down-faulted blocks (Norris, 1981e; Figs. 8.3, 8.31–8.34). Jurassic strata of the Bug Creek Group unconformably overlie the Permian. South of the arch and eastward toward the Interior Platform, the Permian is truncated within a short distance beneath the regional sub-Jurassic disconformity. This package, of Sakmarian to Wordian age, generally comprises three unnamed units (Bamber and Waterhouse, 1971, fig. 10, p. 83) – a basal unit of sandstone, conglomerate and local carbonates (100–200 m thick), a middle unit of calcareous and silty shale with thin carbonate beds and nodules (200–?700 m thick), and an upper unit of calcareous sandstone with subordinate siltstone and shale (250–800 m thick). According to Bamber and Waterhouse (1971) and Henderson et al. (1993,

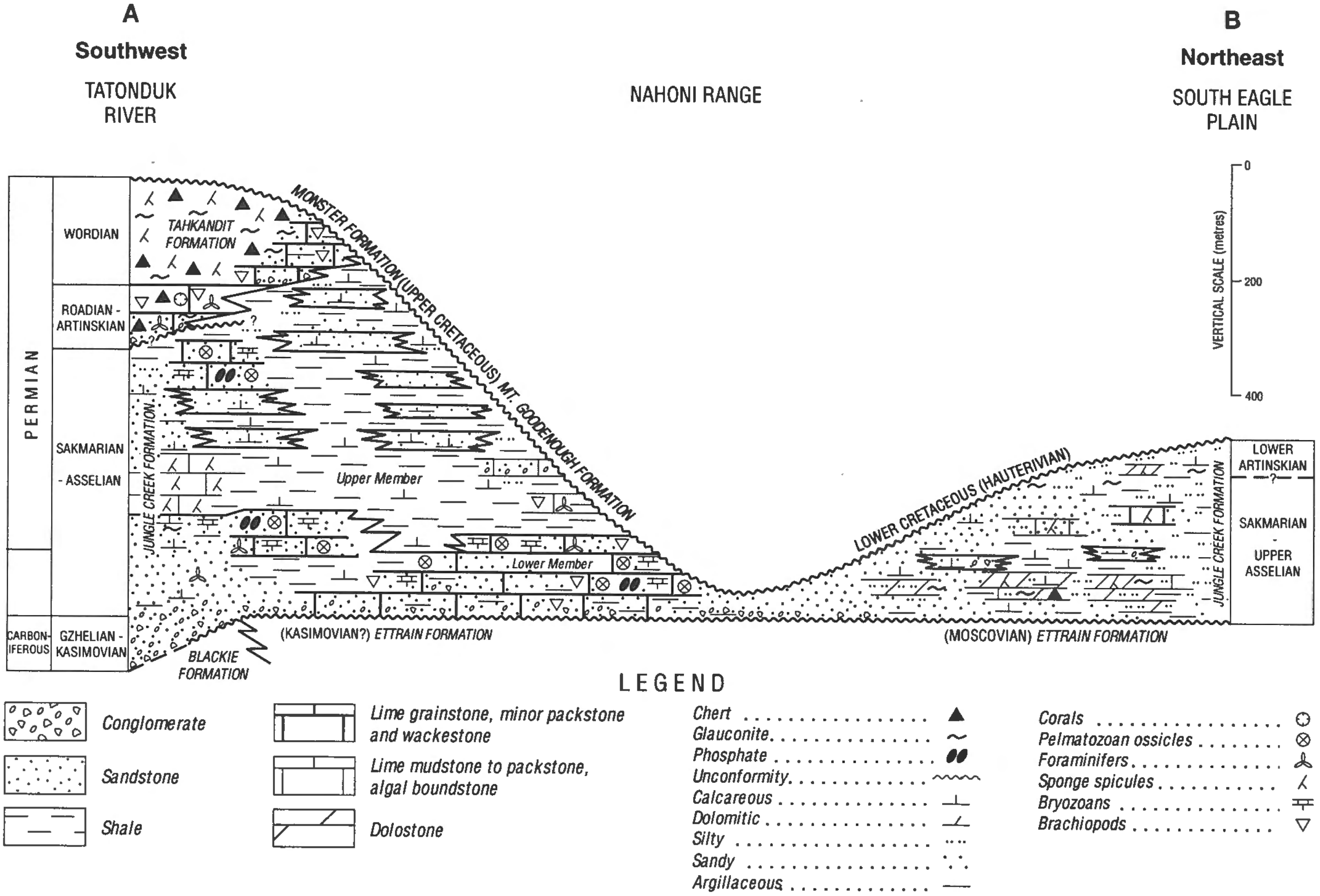


Figure 8.35. Schematic stratigraphic cross-section A–B showing the Permian succession of the Ogilvie Mountains and the Eagle Plain (after Henderson et al., 1993). See Figure 8.1 for the line of section.

fig. 4F13), the Permian thins substantially toward the axis of the uplift and the age of its basal deposits become younger. However, recent field work indicates that the Permian succession across the crest of the former arch is thicker and more complete than previously thought (J. Dixon, pers. comm., 1994). The medial unit appears to thin toward the crest of the arch, but on the crest, the thicknesses and stratigraphic relations of units within the Permian succession are uncertain. In Figure 31, the apparent thinning toward the crest of the former high may reflect depositional thinning toward a northeastern paleoshoreline instead of the effects of a Permian arch. On the north side of the arch, the Permian extends into the northernmost Richardson Mountains, where a fourth unit comprising shallow water carbonates and associated *Palaeoaplysina* mounds (Davies, 1971, 1988; Nassichuk and Bamber, 1978) is developed near the base.

The medium to thick bedded basal unit (Figs. 8.33, 8.34) comprises fossiliferous sandstone (subchertarenite and chertarenite) with subordinate pebble and granule conglomerate and minor limestone (Bamber, 1972, p. 146–149). On the flanks of the Ancestral Aklavik Arch, Sakmarian faunas occur in this resistant unit, which may become younger toward the central part of the arch. There, it rests with angular unconformity on Lower Silurian to Devonian rocks. Conglomerate beds and lenses are most abundant in the lower part of the unit, although locally present throughout. Well rounded to subrounded chert granules and pebbles predominate in the coarse fraction; quartz granules and pebbles are also common. Bedding boundaries within this well bedded, fining-upward basal unit are mainly subplanar. Tabular crossbedding, occurring as sets that are mainly less than 0.15 m thick but locally as thick as 0.9 m, is common. Brachiopods are moderately common throughout, and reworked Viséan miospores are exceedingly abundant.

On both flanks of the arch, coarse grained siliciclastics of the basal unit pass outward, away from the axis, into correlative, fine grained siliciclastics of the recessive middle unit (Figs. 8.31, 8.34). The contact between the lower and middle units is generally abrupt. Sandstone beds resembling those of the lower unit are common in the lower part of the middle unit, where they are interbedded with shale. Above its basal beds, most of the middle unit comprises shale and mudstone rhythmically interbedded with calcareous to argillaceous siltstone beds that resemble tempestites and become more abundant upward (Bamber, 1972, p. 145–146). The principal macrofossils in this middle unit are scattered brachiopods and goniatites.

The Roadian to Wordian upper unit, which gradationally overlies the middle unit, becomes more resistant and more coarsely grained upward (Figs. 8.31, 8.34). The base of this upper unit lies near the Artinskian–Roadian boundary. An unconformity has not been observed either at or near the contact (J. Dixon, pers. comm., 1994), although the basal contacts of most Roadian to Wordian successions elsewhere in western and northern Canada are unconformable (Henderson, 1989; Beauchamp et al., 1989b). In general, the upper unit resembles the sandstone-dominated lower unit but lacks the abundant conglomerate and locally contains a substantial proportion of limestone. Slightly glauconitic sandstone (chertarenite and subchertarenite), with subordinate shale, siltstone and limestone, constitutes this medium to thick bedded unit (Bamber, 1972, p. 142–144). Shale and mudstone are generally rhythmically interbedded with the more resistant rock types, particularly in the basal facies. Minor chert pebble conglomerate is locally present near the top of the unit. Most of the unit is well bedded, and bedding surfaces are commonly subplanar. Abundant brachiopods are preserved in the terrigenous clastics and limestone; *Zoophycos* is common.

The lower and middle units of the unnamed Permian succession jointly constitute a transgressive/regressive sequence; basal lithofacies of the upper unit may be part of this sequence as well. Marine sedimentation during a major transgression and early phase of a subsequent regional regression is shown by the occurrence of the lower and middle units above a subaerial erosion surface developed on the Ancestral Aklavik Arch. Supratidal and beach to tidal flat deposits are probably preserved in the lower sandstone-dominated unit because it includes redbeds of deltaic aspect in the east (J. Dixon, pers. comm., 1994), resulted from the gradual onlap of a subaerial erosion surface, has planar bedding, and is coarse grained. In the west, deposition mainly in shoreface environments and on offshore bars is suggested by the lack of documented subaerial indicators and swash cross-stratification, and by the common preservation of medium-scale tabular crossbedding. Overlying, shale-dominated facies of the middle unit were deposited below fair weather wave base in offshore settings and record the culmination of the transgression. The early part of the subsequent regression, which culminated with late Artinskian subaerial erosion in most parts of western and northern Canada and possibly in the study area as well, is shown by the upper beds of the middle unit and possibly the basal beds of the upper unit.

Above its Artinskian? basal beds, the Roadian to Wordian, sandstone-dominant upper unit is probably also a transgressive/regressive sequence. In the upper unit, deposition in principally lower shoreface to offshore environments is suggested by the predominance of relatively fine grained deposits lacking conspicuous medium- and large-scale crossbedding, and by the presence of abundant trace fossils characteristic of low energy settings. These deposits onlapped either a sub-Roadian unconformity or a conformable sequence boundary. Late Wordian to Early Triassic and subsequent regressions produced the subaerial unconformity at the top of the succession.

Jungle Creek Formation. Gzhelian to Wordian siliciclastics and carbonates of the Jungle Creek Formation constitute most of the Permian succession throughout the Ogilvie Mountains and southern Eagle Plain (Figs. 8.23, 8.32, 8.35). This formation, which generally unconformably overlies the Carboniferous Ettrain and Blackie formations, is 425 m thick at its type section on the Tatonduk River near the Alaska border (Bamber and Waterhouse, 1971, p. 60–62). It reaches a maximum thickness of more than 703 m near the Alaska border to the north, where the lower Jungle Creek includes uppermost Carboniferous (Kasimovian? and Gzhelian) strata (Figs. 8.2, 8.3, 8.35; Waterhouse and Waddington, 1982) and locally may rest conformably on the Ettrain and Blackie formations. Elsewhere, the basal Jungle Creek ranges in age from Asselian to Sakmarian.

In most of the western Ogilvie Mountains, the Jungle Creek Formation is overlain by the Permian Tahkandit Formation, but east of the erosional edge of the latter, the Jungle Creek is truncated by the sub-Cretaceous regional unconformity. The Jungle Creek–Tahkandit contact is mainly conformable and diachronous in Yukon Territory, but along the Alaska border it is an unconformity. On the lower Tatonduk River, the boundary between these two formations is of early Artinskian age (Bamber and Waterhouse, 1971, fig. 7). It becomes younger eastward into the Nahoni Range, where the upper Jungle Creek contains Roadian and ?Wordian correlatives of the Tahkandit

Formation. In the eastern Ogilvie Mountains and southern Eagle Plain, Cretaceous strata overlie the Jungle Creek and truncate it toward the north (D.K. Norris, 1981g, 1982a, 1985).

In the western Ogilvie Mountains, immediately southeast of the Ancestral Aklavik Arch, two unnamed members constitute the Jungle Creek Formation (Bamber and Waterhouse, 1971, p. 62). The formation in this region, which includes the type section, is a fining-upward succession comprising glauconitic and phosphatic terrigenous clastics with subordinate sandy to silty limestone (Fig. 8.29). The lower member (137–220 m thick), coarser grained and more resistant than the upper member, consists of Gzhelian and lower Asselian sandstone (chertarenite; Fig. 8.36), chert pebble-to-granule conglomerate, sandy skeletal lime grainstone and packstone, and subordinate calcareous shale. The upper member (290–>440 m thick) comprises Asselian to ?Wordian sandstone, shale, siltstone, and subordinate carbonates that commonly form coarsening-upward sequences. The upper member is well bedded, with sandstone and carbonate beds intercalated with argillaceous partings and beds. Most bed boundaries in this upper member are subplanar to hummocky.

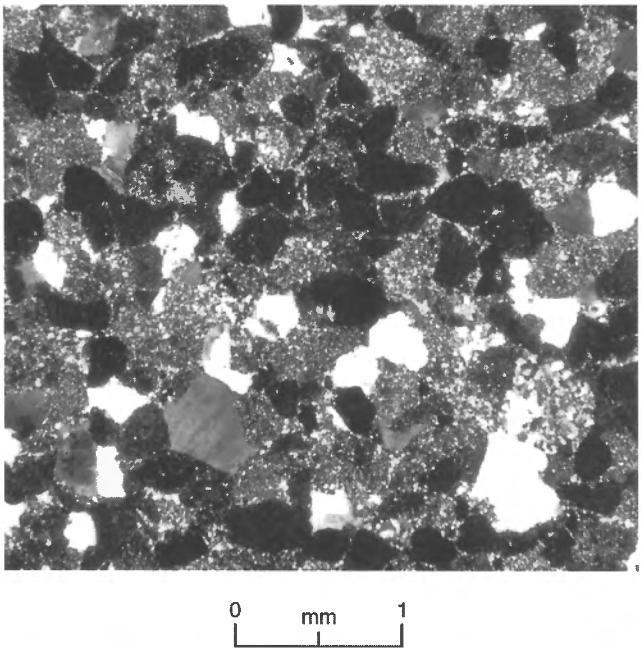


Figure 8.36. *A photomicrograph of medium sandstone — slightly phosphatic, siliceous, mature chertarenite — from the type section of the Permian Jungle Creek Formation, Tatonduk River, western Ogilvie Mountains, Yukon (GSC loc. C-71392). ISPG photo 3509-55.*

Southward and southeastward, away from the Ancestral Aklavik Arch, the Jungle Creek Formation becomes more finely grained and has not been divided into members. In this region, siliciclastics and sandy carbonates of the formation grade into spicular carbonates, chert, and shale (?Blackie Formation; Pugh, 1983, p. 48).

In southern Eagle Plain, farther to the east, the Jungle Creek Formation consists of fine grained sandstone, siltstone, shale, and subordinate carbonates (Fig. 8.35). These appear to pass southward, through the eastern Ogilvie Mountains, into an undifferentiated succession of shale, siltstone, and silty carbonates (Graham, 1973).

Sandstone within the formation is mainly very fine to medium grained chertarenite (Fig. 8.36), but coarser grained beds are present. Most of the sandstone is moderately phosphatic (3–7% phosphatic clasts); glauconite is also common. Chert and quartz constitute most of the sand-size and coarser grained terrigenous fraction; feldspar is rare. Reworked Carboniferous conodonts, carbonate lithoclasts, and calcareous fossils are common in the sandy limestone along the Peel River of southern Eagle Plain.

Regional stratigraphic relations and lithofacies of the transgressive Jungle Creek Formation suggest deposition in shoreline to offshore settings. Deposition at least partly in retrograding shoreline settings is indicated by the presence of this unit above a regional subaerial unconformity and by the occurrence of cross-stratified coarsening-upward sequences in the west. A transition to offshore shelf and possible slope settings is recorded by a southward to eastward gradation from coarse grained siliciclastics and sandy limestone to shale, siltstone, chert, and spicular carbonates. The Jungle Creek records a major transgression, also indicated by the lower and middle units of the unnamed Permian succession in the northern Richardson Mountains. A subsequent Artinskian regression, best represented by the overlying basal Tahkandit Formation, is probably also indicated by Artinskian deposits of the western Jungle Creek Formation.

Tahkandit Formation. The Tahkandit Formation (Figs. 8.3, 8.35, 8.37) is a sequence of Permian limestone, sandstone, and conglomerate named in east-central Alaska by Mertie (1930). In the Yukon Territory, resistant terrigenous clastics, carbonates and chert of the Artinskian to Wordian Tahkandit Formation (29–410 m thick) outcrop in the Ogilvie Mountains in the southwestern corner of the study area (D.K. Norris, 1981g, 1982a) and extend southeastward into the eastern Ogilvie Mountains of the Dawson, Larson Creek and Nash Creek 1:250 000 map areas (Green, 1972).

The eastward-thinning Tahkandit Formation generally conformably overlies and passes eastward into the upper Jungle Creek Formation. In western outcrops of the study area, however, the contact between the Jungle Creek and the chert pebble conglomerate and conglomeratic limestone of the basal Tahkandit is a minor disconformity. The magnitude of this break increases rapidly westward in adjacent east-central Alaska, where the Tahkandit onlaps a subaerial erosion surface developed on the Ancestral Aklavik Arch. In east-central Alaska, the Tahkandit grades northwestward into the Step Conglomerate (Brabb, 1969, p. 18).

In the study area, Jurassic terrigenous clastics of the Kingak Formation and Cretaceous deposits of the Monster and Mount Goodenough formations unconformably overlie the Tahkandit. Toward the east, the Tahkandit is truncated beneath the sub-Cretaceous unconformity (Fig. 8.35; D.K. Norris, 1981g, 1982a, 1985).

At its northern outcrops in the Ogilvie Mountains, nearest to the axis of the Ancestral Aklavik Arch, the Takhandit Formation comprises fine to coarse grained, partly sandy and glauconitic lime grainstone, minor sandstone (chertarenite) and conglomerate, and relatively little bedded chert, as in the type area in adjacent Alaska (Bamber and Waterhouse, 1971, p. 66–69; Brabb and Grant, 1971). Chert clasts constitute most of the coarse fraction in the conglomerate, but upper Paleozoic carbonate lithoclasts are moderately common (Fig. 8.38). The siliciclastics are most abundant in the lower part of this slightly phosphatic, fining-upward formation. The proportion of bedded chert increases toward the south and southeast, where the formation is dominantly spicular chert and fine grained limestone (Bamber and Waterhouse, 1971, p. 68, 69; Green, 1972).

The Tahkandit Formation is dominated by fine grained, offshore shelf and slope deposits but contains basal, shoreline lithofacies in the west. Deposition partly in shoreline (mainly shoreface) settings is suggested by the occurrence of fossiliferous, coarse grained basal deposits that lack subaerial indicators but lie on a subaerial unconformity. A transition to deposition in offshore shelf and possible slope settings is recorded by the southeastward gradation from the coarse grained basal beds to bedded, spicular chert and fine grained limestone. In east-central Alaska, the presence of the Tahkandit and correlative Roadian to Wordian Step Conglomerate above an erosion surface developed on Precambrian to upper Paleozoic strata records transgression and onlap of southwestern Ancestral Aklavik Arch. These stratigraphic relations indicate that part of the Ancestral Aklavik Arch remained exposed into the Late Permian.

Figure 8.37. Sandy limestone and overlying light to medium grey, bedded chert and cherty, spicular carbonates of Permian Tahkandit Formation (base not shown, arrow indicates top) overlain by the Cretaceous Monster Formation, north side Tatonduk River, above the type section of the Jungle Creek Formation, western Ogilvie Mountains. ISPG photo 3407–5.

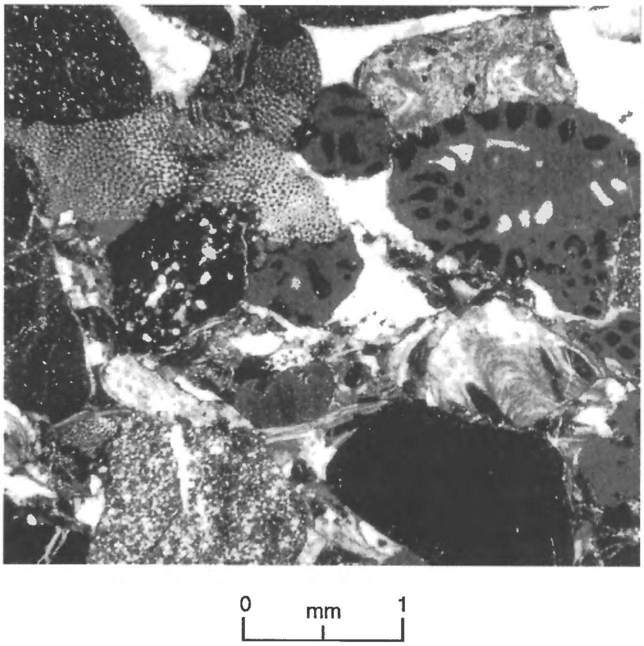


Figure 8.38. A photomicrograph of conglomeratic, very coarse sandstone — calcareous chertarenite — from basal Tahkandit Formation on Tatonduk River, western Ogilvie Mountains. The sample contains abundant fragmentary fusulinaceans and pelmatozoan ossicles and scattered lithoclasts of Paleozoic limestone (arrow) (GSC loc. C-71355). ISPG photo 3509-63.

Step Formation. Roadian to Wordian siliciclastics and carbonates of the Step Formation (Fig. 8.4), a northwestern correlative of the Tahkandit Formation, are preserved mainly in east-central Alaska, north of the Yukon River (Brabb, 1969, p. 17-19). That region includes the Step Mountains, where about 600 m of strata constitute the incomplete type section. In Canada, the Step Formation, deposited on the Ancestral Aklavik Arch, has been mapped in a small area along the Yukon/Alaska border in the central Ogilvie River map area less than 2 km north of the Nation River (D.K. Norris, 1982a, 1985).

The Step Conglomerate of Alaska unconformably overlies Precambrian to Lower Carboniferous and Permian? rocks (Brabb, 1969; Brabb and Churkin, 1969; Brosge and Dutro, 1973). In the study area, it unconformably overlies an undated marine succession that probably includes upper Paleozoic strata (D.K. Norris, 1982a, 1985). The Step Formation is dominantly chert-pebble conglomerate and fossiliferous sandstone, but units of sandy to conglomeratic skeletal limestone resembling those of the Tahkandit are present. The Yukon occurrence has some coarser grained conglomerate containing chert boulders up to 15 cm in diameter.

Deposition in shallow marine settings is demonstrated, at least in part, by the presence of abundant brachiopods in the limestone units and in some sandstone and conglomerate. Nonmarine deposits may also be present because the Step Formation onlapped the subaerially exposed Ancestral Aklavik Arch. A transgression, recorded by the Tahkandit Formation as well, is indicated by the onlap relationship. The Step and its coeval correlatives in the Tahkandit Formation represent a transgressive-regressive sequence largely eroded during regional Late Permian to Early Triassic and subsequent regressions.

Sadlerochit Group. The western British Mountains contain a thin, poorly known Permian succession deposited in an unnamed Permian basin developed north of the Ancestral Aklavik Arch. In that region, Lower Permian shale, sandstone, and minor carbonates of the Sadlerochit Group, up to 200 m thick, are preserved as local erosional remnants above Upper Carboniferous (Bashkirian) carbonates of the Lisburne Group (Bamber and Waterhouse, 1971). Permian facies relationships and environments of deposition in this northern area are not known. Terrigenous clastics of the Triassic Shublik Formation and Jurassic Kingak Formation unconformably overlie the Sadlerochit of the study area (D.K. Norris, 1983, 1985).

The Sadlerochit Group extends into adjacent northern Alaska, where it is widely preserved and comprises the Permian Echooka Formation and overlying Triassic Ivishak Formation (Detterman et al., 1975; Sable, 1977; Crowder, 1990). The Echooka, deposited in continental to shallow marine shelf environments, records the transgression of a regional unconformity resulting from Late Carboniferous subaerial erosion. Nonmarine conglomerate of the basal Echooka fills erosional channels and valleys and grades upsection into a retrogradational succession dominated by tempestites (Crowder, 1990).

Provenance of terrigenous clastics

Upper Devonian and Carboniferous

Sedimentary and low-grade metamorphic rocks provided most of the siliciclastics in the Upper Devonian and Carboniferous succession, as exemplified by the clast composition of the sandstone and conglomerate and the characteristics of the quartz clasts in these rocks. Most of the granules, cobbles and boulders are chert, vein quartz (Figs. 8.13, 8.26, 8.27), and siltstone to sandstone, whereas coarse grained plutonic clasts are relatively rare, and volcanic rock fragments were not observed. Within the sand fraction, chert and quartz clasts predominate; heavy minerals, feldspar and mafic silicate minerals are minor constituents. Chert clasts are commonly more abundant than those consisting of quartz, thereby indicating that chert-bearing carbonate rocks and bedded chert were the main source overall. Low-grade metamorphic rocks containing abundant quartz were probably the main source of terrigenous clastics in the Kekituk and were the second or third most important sources of grains for most other formations. This is demonstrated by the numerous granules to cobbles of vein quartz in the Kekiktuk, and by the presence of abundant quartz with undulatory extinction in other units. Plutonic rocks, although moderately widespread in the study area and adjacent Alaska, appear to have been a relatively minor source.

Sedimentary and low-grade metamorphic rocks in the Yukon Fold Belt, and to a lesser extent in the Ellesmerian Fold Belt (Figs. 8.5, 8.6) and flanking uplifted regions, supplied the bulk of the terrigenous clastics in the Upper Devonian and Carboniferous formations. The Ancestral Aklavik Arch, which developed on the southern Yukon Fold Belt, was an additional major source during the Gzhelian and possibly the Kasimovian. These interpretations are supported by: the clast composition of the terrigeous clastics, regional lithofacies trends and stratigraphic relationships discussed throughout the text (Figs. 8.8, 8.9, 8.11, 8.14), and paleocurrent direction indicators in the Imperial Formation.

The highly deformed lower Paleozoic succession preserved in the Yukon Fold Belt is dominated by sedimentary rocks and low-grade metasediments (Cecile, 1988; Lane and Cecile, 1989) that were extensively subaerially exposed from the Frasnian into the Late Carboniferous. Chert, which is widespread, includes a distinctive green variety resembling that of coarse clasts in the Tuttle Formation and other Upper Devonian and Carboniferous formations. Vein quartz, resulting from pre-Late Devonian deformation is also common. The Yukon Fold Belt was, therefore, a suitable provenance for most of the Upper Devonian and Carboniferous terrigenous clastics.

A second major source area was the Ellesmerian Fold Belt, which lay in the area of the present-day Arctic Archipelago (Fig. 8.5). During the Late Devonian to earliest Carboniferous Ellesmerian Orogeny and a subsequent late Viséan episode of blockfaulting (Kerr, 1981, p 145–146; Beauchamp et al., 1989a), a thick widespread succession of Middle to Upper Devonian sandstone in the Ellesmerian Fold Belt was uplifted along with older chert-rich strata and subordinate metamorphic and igneous rocks. Most of the vast area uplifted was subaerially exposed throughout the Early Carboniferous (Nassichuk, 1975, p. 23; Thorsteinsson, 1974, p. 17–23; Kerr, 1981, p. 129, 142–146).

Regional lithofacies trends and stratigraphic relationships also support the interpretation that the Yukon and Ellesmerian fold belts were the main source areas for the terrigenous clastics in the study area. Formations dominated by terrigenous clastics show coarsening and thickening trends toward the northwest and the northeast, the direction of the Yukon and Ellesmerian fold belts respectively (Figs. 8.8, 8.9, 8.11, 8.14). Similarly, spatial relationships between the lithofacies indicate that Late Devonian to Early Carboniferous terrigenous shoreline and deltaic systems prograded basinward or away from from the two orogenic belts. Sole marks on the bases of the turbidites in the Imperial Formation indicate sediment transport from the north (A.W. Norris, 1985, p. 34).

Permian

The Ancestral Aklavik Arch was an important source for Permian terrigenous clastics in east-central Alaska and much of the study area, particularly during the Asselian and Sakmarian. This interpretation is best supported by the onlap relationship between the arch and the Permian succession. Additional support is provided by an analysis of clasts within the Permian formations. Chert and quartz clasts derived mainly from sedimentary and low-grade metamorphic rocks dominate the terrigenous component of the Permian sandstones and conglomerates (Figs. 8.36, 8.38). Abundant, reworked Carboniferous microfossils — conodonts, miospores, and foraminifers — are also present. During the latest Carboniferous, the Upper Carboniferous to lower Paleozoic and Precambrian sedimentary rocks and low-grade metasediments that constitute the arch were uplifted and subjected to deep subaerial erosion, thereby providing a suitable source for the clasts.

Prior to the Artinskian, the northeastern Ancestral Aklavik Arch had been completely onlapped by conglomerate and sandstone. The latter demonstrates that the arch was not the sole source of the Permian siliciclastics deposited on and adjacent to the uplift. Another source area was Crockerland, the northwest rim of the Sverdrup Basin (Embry, 1992). Paleozoic strata were also exposed along the northeastern side of Ishbel Trough and could have been a major sediment source.

Permian siliciclastics in the Sadlerochit Formation of the western British Mountains and north slope of Alaska were derived from a region lying northeast of the Brooks Range and the British Mountains (Brosgé and Dutro, 1973, p. 370). This is shown by northeastward coarsening trends in Alaska and by the fact that the Permian deposits in Alaska wedge out northeastward (Bird, 1988, fig. 16.12) onto a Permian high. The latter was a northern remnant of the formerly widely exposed Yukon Fold Belt or Barrovia and was probably part of Crockerland.

Paleolatitude and paleoclimate

Paleolatitude

Numerous Late Devonian, Carboniferous and Permian paleogeographic reconstructions using paleomagnetic and other geologic data have been made for North America (Irving, 1977; Ziegler, 1988; Van der Voo, 1988; Scotese and McKerrow, 1990; Rowley et al., 1985; Johnson and Tarling, 1985; Tarling, 1985; Keppie, 1977; Wynne et al., 1983; Bambach et al., 1980). The reconstructions suggest that the study area lay between latitudes 15°N and 25°N during the Late Devonian, 20°N and 35°N during the Carboniferous (Figs. 8.5, 8.6), and 30°N and 40°N during the Permian. Most of the region would have lain in the tropics (between the equator and the tropic of Cancer) during the Late Devonian, the subtropical zone during the Carboniferous, and the subtropical to temperate zones during the Permian — indicating a northward migration of about 15° to 20° latitude from the Late Devonian to the Late Permian.

Paleoclimate indicated by lithofacies

The climate of the study area and northeast Alaska was semiarid to moderately humid from the Frasnian through the early Tournaisian. Coal is only locally present as a minor component in the nonmarine pre-upper Tournaisian deposits in the study area and adjacent Alaska, but carbonaceous fragments and macroscopic terrestrial plant remains are moderately common (Brabb and Churkin, 1967, p. D9; Nilsen and Moore, 1984; Brosgé et al., 1988; Pugh, 1983, p. 43; Brabb, 1969, p. 15-17). Therefore, during the late Devonian and earliest Carboniferous, there was probably sufficient water for some plant growth and the development of fluvial to deltaic systems, but not for the development of coal swamps and peat. Paleosols associated with redbeds are common in the Kanayute Formation (Nilsen and Moore, 1984; Brosgé et al., 1988, p. 305) and indicate extended periods of relatively dry conditions. Evaporites, arid climate indicators, have not been reported.

Middle Tournaisian through Viséan climates were generally very humid to moderately humid, but there was a trend toward increased aridity. Within the study area, coal seams (Fig. 8.9) and macroscopic terrestrial plant remains are common in Viséan deposits of the Kayak Formation (Cameron et al., 1986; Bamber and Waterhouse, 1971, p. 75) and in unnamed middle? Tournaisian and Viséan correlatives of the Ford Lake Formation that lie in southwestern Peel Plateau (Bamber and Waterhouse, 1971, p. 50-51). In Alaska, fan delta deposits of the Kekituk Formation, mainly coeval with the lower Kayak, also accumulated under humid or wet conditions (Bloch et al., 1990, p. 1374). Evaporites and their pseudomorphs are lacking in the Tournaisian to middle Viséan deposits. The existence of extensive areas containing coal and lacking evaporites strongly suggests widespread wet climates (Witzke and Heckel, 1988). In northern Alaska, abundant calcite pseudomorphs of gypsum are preserved in upper Viséan strata of the Alapah Formation (Armstrong and Mamet, 1975, p. 22). The presence of the pseudomorphs indicates that the late Viséan climate of northern Alaska was at least seasonably semiarid to arid.

A trend to slightly dryer post-Viséan Carboniferous and Early Permian climates is suggested by the lack of macroscopic terrestrial plant remains and coal seams in peritidal deposits of the study area and northern Alaska. It is also suggested by climatic indicators in the adjacent Sverdrup Basin. The late Serpukhovian to Moscovian climate of the Sverdrup Basin was hot and arid, as exemplified by the thick subaqueous evaporites of the Otto Fiord Formation (Nassichuk and Davies, 1980).

From the late Artinskian to Roadian, the climate may have become more humid, as it did in the Sverdrup Basin (Utting, 1989, p. 239).

Within the study area and northern Alaska, the Carboniferous shallow water carbonates are of tropical to subtropical aspect. Such carbonates typically develop in warm water (mean temperature above 23°C) between latitudes 30°N and 30°S, but locally intruding warm or cold oceanic currents can displace this boundary by 5° to 10° latitude, or more (Lees, 1975; Nelson, 1988). Deposition of the Carboniferous shallow water carbonates in dominantly warm water tropical and subtropical settings is indicated by the widespread occurrence of abundant ooids in the western Ettrain and Wahoo formations, and by numerous calcareous green algae in the Alapah (Figs. 8.8, 8.9, 8.30). Ooids are common in warm water, tropical to subtropical, shallow marine carbonate deposits but typically absent from those formed in the cool water (12-20°C) of temperate climates (Nelson, 1988). Calcareous green algae are significant components of the tropical-subtropical skeletal-grain association of Lees (1975), and minor constituents of his temperate water assemblage. Other tropical and subtropical, warm water indicators that are common in the Alapah Formation of Alaska are stromatolites, fenestrate cryptalgal laminites, and laminated algal-mat dolostone (Armstrong and Mamet, 1975, p. 22).

Cool water Carboniferous carbonates are also widely preserved in the region, but they are of outer shelf margin to basin origin. In the Hart River and Blackie formations and southwestern Alapah, cool water, shelf margin to basin conditions are represented by impoverished associations dominated by echinoderms, bryozoans, and siliceous sponges.

Most Permian carbonates of the study area are characteristic of cool water and may have formed in a temperate climate. Deposition, dominantly in cool water, is suggested by the high proportion of terrigenous clastics (Figs. 8.31, 8.35), rare in warm water tropical and subtropical carbonates (Nelson, 1988), and by the occurrence of abundant glauconite in the Jungle Creek and Tahkandit formations. Glauconite is rare in warm water, tropical to subtropical, marine carbonates but common in those formed in the cool water of temperate climates (Nelson, 1988, Table 1). Temperature is not a primary control of glauconitization, but it greatly influences rates of carbonate production. Slow sedimentation rates and a source of abundant iron favor glauconitization (Odin and Morton, 1988). Deposition in cool water is also demonstrated by the impoverished cool water Asselian, and early Roadian to Wordian, brachiopod faunas (Bamber and Waterhouse, 1971, p. 188). Wordian carbonates of the Tahkandit Formation are associated with bedded spicular chert, another cool water indicator. Low faunal diversity is characteristic of cool water, temperate climate, marine carbonates (Nelson, 1988; Beauchamp et al., 1989a).

An exception to the cool water Permian carbonates discussed above occurs in the northernmost Richardson Mountains, where lower Sakmarian *Paleoaplysina* bioherms are preserved. Because reefs commonly develop in warm, tropical to subtropical water, rarely in cool water, the early Sakmarian shallow water in this region was probably warm and the climate, tropical to subtropical.

Paleoclimate indicated by palynomorphs

Upper Devonian deposits of the Imperial and Tuttle formations contain a diverse assemblage of palynomorphs (Braman, 1981), suggesting a moderately humid climate.

Late Tournaisian to early Viséan palynological assemblages from the British Mountains (Kekiktuk and lower Kayak formations) are dominated by trilete spores. They include abundant specimens of *Densosporites*, and common *Tripartites incisotrilobus* (Naumova) Potonie and Kremp, *Monilospora*, *Tumulispora rarituberculata* (Luber) Turnau, and *Cingulizonates*. These taxa, according to Van der Zwan et al. (1985), suggest that the parent land plants lived in a moderately humid climate. Assemblages from the eastern Kayak closely resemble those from the upper Tournaisian and lower Viséan in terms of most environmentally important taxa present. This resemblance suggests that the humid climate persisted into the late Viséan in the northern part of the study area. Climatic conditions may have been slightly dryer in the southern part of the study area. In the type section of the Hart River Formation on the Peel River, Viséan assemblages contain the following humid-climate indicators: *Murospora aurita* (Waltz) Playford, *Monilospora*, *Cirratriradites*, *Densosporites*, *Reticulatisporites*, *Dictyotriletes*, *Raistrickia*, and *Rotaspora*. There are, however, some elements that Van der Zwan et al. (1985) consider to be dry climate indicators - *Crassispora trychera* Neves and Ioannides, and *Rugospora* (Bamber et al., 1989; Utting, 1991).

The moderately humid late Tournaisian to late Viséan climate of northern Yukon extended to the developing Sverdrup Basin (Fig. 8.6), where lacustrine deposits of the upper Viséan Emma Fiord Formation were being deposited in an area with a high temperature (Davies and Nassichuk, 1988). It also extended to Spitsbergen, the Donetz Basin, and the Pripyat Depression of Russia (Van der Zwan et al., 1985; Utting et al., 1989). This vast belt falls into the warm, humid "*Lophozonotriletes* region" of Van der Zwan (1981). Clayton (1985) termed this the *Monilospora* microflora and suggested deposition in an equatorial to low latitude position.

Serpukhovian climates were still humid, but there was a clear trend toward increased aridity from the Moscovian to early Artinskian. Monosaccate pollen of undetermined climatic significance appear in the lower Serpukhovian strata of the uppermost Hart River Formation, but many humid-climate taxa found in the Viséan persist. In lower Bashkirian facies of the Blackie Formation, a diverse assemblage of trilete spores, suggesting a humid climate, continues to predominate, but monosaccate pollen become abundant; rare striate and nonstriate disaccate pollen appear (Bamber et al., 1989). Asssemblages from uppermost Bashkirian to lower Moscovian deposits of the Blackie and Ettrain are dominated by monosaccate pollen. Striate and nonstriate disaccate pollen and the polyplicate genus *Vittatina*, which is diagnostic of dry climates, are rare. The abundance of monosaccate pollen, some related to *Cordaites*, suggests that conifers dominated the parent vegetation. *Vittatina* and striate disaccate pollen become common in the upper Moscovian of northern Yukon (Bamber et al., 1989), recording increased aridity. This trend continues into the Gzhelian and peaks in the Asselian and Sakmarian, as indicated by the predominance of *Vittatina* in the Jungle Creek Formation.

No palynological data are available from post-Sakmarian Permian beds of northern Yukon, but data from the adjacent Sverdrup Basin record two main climatic changes that probably influenced the study area. In the upper Artinskian to Roadian (Sabine Bay and Assistance formations), there is a diversity of trilete spores indicating that more humid conditions succeeded the earlier hot, arid climate. This interpretation is supported by the occurrence of thin coal seams in the Sabine Bay Formation (Tozer and Thorsteinsson, 1964, p. 101). The Wordian (Trold Fiord Formation) assemblages are less diverse again and dominated by striate disaccate and polyplicate pollen, recording a return to arid conditions (Utting, 1989, p. 239).

Tectonic history

Late Devonian and Carboniferous

Frasnian to middle Tournaisian

From the Frasnian into the Tournaisian, the Ellesmerian Orogeny profoundly influenced the geography and depositional history of the study area and adjacent areas. The Ellesmerian Orogeny is clearly recorded in northern Yukon and northern Alaska by the deformed, intruded, and metamorphosed pre-Carboniferous rocks of Yukon Fold Belt and by the synorogenic deposits in flanking troughs (Figs. 8.5, 8.8, 8.24). Convergence between the oceanic crust of the paleo-Pacific Ocean and the North American and Chukotka plates of Laurussia was probably the principal cause (Fig. 8.5; Ziegler, 1988, fig. 6). In response to the contractional event, pronounced Late Devonian and earliest Carboniferous subsidence took place in the compressional foreland basin (northern Mackenzie Basin and its successor, Prophet Trough) lying east of the Yukon Fold Belt. Profound subsidence also took place in the back-arc basin (western arm of Prophet Trough) lying between the Yukon Fold Belt and the volcanic/plutonic belt to the west. The main sedimentological record for the orogeny in northern Yukon is the thick flysch of the Upper Devonian Imperial Formation, the overlying conglomeratic "molasse" deposits of the Upper Devonian to lowermost Carboniferous Tuttle Formation, and the Upper Devonian to Tournaisian shale and sandstone of the lower Ford Lake Formation (Figs. 8.2, 8.8, 8.12).

Late Tournaisian to early Kasimovian

Subsequent to the Ellesmerian Orogeny, extension probably caused most subsidence in the region, as it did in the developing Sverdrup Basin to the northeast (Kerr, 1981, p. 142-147; Beauchamp et al., 1989a) and in most of the Western Canada Sedimentary Basin south of the study area (Richards, 1989). The Yukon Fold Belt was widely exposed during the Early Carboniferous, but gradual subsidence recorded by northeastward onlap took place until the late Viséan, when broad epeirogenic uplift interrupted the trend. Subsidence rates must have been moderately high in the southwest (northern Ogilvie Mountains and Eagle Plain), where moderately deep water deposits of the Ford Lake, Hart River and Blackie formations were deposited above deltaic deposits of the Tuttle in northeastern Prophet Trough (Fig. 8.8). To the north, slower subsidence is suggested by the occurrence of shallow marine lithofacies (Kayak Formation and overlying Lisburne Group) that slowly onlapped the Yukon Fold Belt. Late Viséan blockfaulting (Kerr, 1981) and associated epeirogenic uplift (Beauchamp et al., 1989a) in the adjacent Sverdrup Basin and in the study area (Fig. 8.6; Ziegler, 1988, fig. 7) resulted in a regional late Viséan regression. The latter is recorded by terrigenous clastics of the Kayak Formation in the northeastern British Mountains (Figs. 8.9, 8.20) and by conglomerate and associated carbonates of the eastern Hart River Formation (Fig. 8.8). Regional subsidence resumed in the Serpukhovian and apparently continued into the Moscovian and possibly the Kasimovian(?), as recorded by the transgressive upper Blackie and Ettrain formations in the south and by the Lisburne Group of the northern Richardson Mountains (Figs. 8.35, 8.36).

Kasimovian(?) and Gzhelian

During the Kasimovian(?) and Gzhelian, the Ancestral Aklavik Arch rose. This uplift (Figs. 8.23, 8.31, 8.32), of block fault origin, was well developed by the Early Permian, as indicated by Kasimovian(?) to Gzhelian conglomerate in the basal Jungle Creek Formation (Fig. 8.35). Fault-bounded basins, preserving thick sequences of Upper Devonian and Carboniferous strata, developed along the southern and northern flanks of the arch. Broader, extension-related deformation also took place in Sverdrup Basin (Kerr, 1981; Beauchamp et al., 1989a) and in the study area, where uplift was more pronounced northward and eastward, as suggested by the pre-Permian differential erosion of the Upper Carboniferous succession (Figs. 8.2, 8.8, 8.9).

Permian

In northern Yukon and northwestern District of Mackenzie, Lower Permian depositional patterns and structural relationships at the sub-Permian disconformity indicate local uplift and block faulting along the Ancestral Aklavik Arch (Figs. 8.23, 8.32) in latest Carboniferous and earliest Permian time. Most of the remainder of the Permian was characterized by differential subsidence and onlap of the arch. Episodes of differential uplift may have taken place along Ancestral Aklavik Arch, as suggested by the unconformity between the Jungle Creek and overlying Tahkandit Formation. Permian subsidence resulted largely from regional extension. Marine sedimentation continued in most of the study area into the Wordian and was followed by a period of regression and nondeposition, marked by the North America-wide, sub-Triassic disconformity.

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Fossil collecting in the Upper Triassic Sublik Formation on the south flank of Loney Syncline, Yukon Coastal Lowland. GSC photo 2-10-75.

CHAPTER 9

TRIASSIC

D.K. Norris

Norris, D.K., 1996. Triassic. In *The Geology, Mineral and Hydrocarbon Potential of Northern Yukon Territory and Northwestern District of Mackenzie. Geological Survey of Canada, Bulletin 422, p. 253–265.*

Abstract

The Shublik Formation within the project area is an unconformity-bounded assemblage of carbonates and clastics of Middle and Late Triassic age. It is characterized by two distinct facies: nearshore depositional environments to the north, and deeper water and organic-rich facies to the south. The formation ranges in thickness from zero at its feather edge on Yukon Coastal Lowland to a few hundred metres at the headwaters of Ogilvie River. The northern and eastern erosional limits of the Shublik, as well as those of the upper Paleozoic formations immediately beneath it, follow a curvilinear trace, outlining the fundamental, ancient and persistent shape of the Cordilleran miogeocline and, in turn, the structural grain of the Laramide and earlier deformations imposed upon it. The overstepping of the Shublik onto progressively older formations from southwest to northeast, in addition to the erosional truncation of the Shublik at the sub-Jurassic disconformity, means that the southeastward continuation of the Permian and Triassic hydrocarbon reservoirs at Prudhoe Bay do not reach into mainland Canada and may not be present beneath the continental shelf of southern Beaufort Sea.

Résumé

La Formation de Shublik dans la région à l'étude est un assemblage de roches carbonatées et de clastites du Trias moyen et tardif limité par une discordance. Elle est caractérisée par deux faciès distincts : un faciès littoral au nord et un faciès d'eau plus profonde et riche en matières organiques au sud. La formation varie en épaisseur de nul à sa bordure en biseau sur les basses terres littorales du Yukon à quelques centaines de mètres dans la zone amont de la rivière Ogilvie. Les limites d'érosion nord et est de la Formation de Shublik, ainsi que celles des formations du Paléozoïque supérieur qui lui sont sous-jacentes, suivent un tracé curviligne, délimitant la forme fondamentale, ancienne et persistante du miogéosynclinal de la Cordillère, et ensuite, le grain structural des déformations laramiennes et plus anciennes. La transgression de la Formation de Shublik sur des formations graduellement plus anciennes du sud-ouest au nord-est, en plus d'une troncation par érosion de la Formation de Shublik à la discordance sub-jurassique, signifie que le prolongement vers le sud-est des réservoirs d'hydrocarbures du Permien et du Trias à la baie Prudhoe n'atteint pas le Canada continental et pourrait ne pas être présent sous la plate-forme continentale du sud de la mer de Beaufort.

INTRODUCTION

All the Middle and Upper Triassic rocks in the project area are assigned to the Shublik Formation in this report. Previous studies (Mountjoy, 1967) suggest that highly deformed siltstone and shale homotaxial with the Lower Triassic Ivishak Member of the Sadlerochit Formation may be present along the Alaska border. Moreover, a pebble conglomerate, pebbly sandstone and shale succession, embraced in part within the Brat Creek Formation in northern Richardson Mountains, were tentatively assigned to the Triassic (Jeletezky, 1967). The possible Ivishak equivalents and the Brat Creek are considered further for the sake of completeness, but both may require additional study before they can be integrated into the physical and biostratigraphic history of the region.

Rocks of Late Triassic age in the region were first noted by Maddren (1912, p. 312) as a result of his geological investigations in collaboration with the joint commission appointed by the governments of Canada and the United States to survey the boundary between Yukon Territory and Alaska. These black shales and impure, thin bedded limestones, occurring a few miles west of the international boundary in the upper reaches of Firth River, were ultimately to become the Shublik Formation, mappable from Peel Plateau, on the east flank of Richardson Mountains, across northern Yukon Territory and Alaska.

The Shublik Formation was named and first described by Leffingwell (1919, p. 115–116) in his report on the geology of the Canning River region, Alaska. He designated the type section of the formation on Shublik Island, in Canning River, close to the mouth of Cache Creek. Because of poor exposure there, he obtained stratigraphic details of the Shublik from a section near the southeastern end of the Sadlerochit Mountains.

More recent investigations, however, led Detterman (1970) to discover a better exposed section of the Shublik, including both lower and upper contacts, on Fire Creek, a western tributary of the Sadlerochit River. It was designated the reference section for the formation (Detterman et al., 1975, p. 14). The Shublik Formation is characterized by its distinct lithologies and by its abundance of shelly fossils. It is the only dominantly limestone formation in the Mesozoic succession of northern Yukon Territory and northern Alaska.

Prior to 1962, known occurrences of the Middle and Upper Triassic Shublik Formation in northern Yukon Territory were few in number. In 1962, however, reconnaissance geological mapping by the Geological Survey of Canada added considerably to our knowledge of the distribution and character of the formation (Mountjoy, 1967). Subsequently, additional mapping has resulted in much new data and a more complete understanding of the Shublik within the project area.

The initial regional study of the Shublik in 1962 was under the guidance of E.W. Mountjoy. Several stratigraphic sections were measured and many spot localities described as a result of follow-up work. In addition to Mountjoy, contributors included E.W. Bamber, L.D. Dyke, D. Mayes, A.W. Norris, D.K. Norris and U. Upitis. Triad Oil Company provided information on occurrences of the Shublik on the north flank of British and Barn mountains which was invaluable for strategic planning for the study. Moreover, the company kindly granted permission to publish its data on fossil collections from the Shublik (see Mountjoy, 1967, p. 42–43). E.T. Tozer examined and reported on all Shublik collections made within the project area. B.L. Mamet (University of Montreal), J.B. Waterhouse (The University of Queensland), and T.T. Uyeno identified fossils as reported in the text.

Data from new localities, notably on the southwest flank of British and Barn mountains and on lower Firth River, have proven essential to a fuller understanding of the physical- and biostratigraphy of the Shublik.

LITHOFACIES

The Shublik Formation within the project area is an unconformity-bounded assemblage of: dark grey to sooty black, argillaceous, finely crystalline to skeletal limestone; black limy mudstone; black shale with ironstone concretions; dark grey, calcareous siltstone; light to dark grey, fine grained, calcareous sandstone; and medium and dark grey, massive chert. The basal beds are characteristically conglomeratic, with subrounded pebbles and cobbles of white quartzite and grey and green chert. The formation is commonly rich in monotid and halobiid bivalves, with some beds being made up wholly of these flat shells. Coquinas appear to be associated with most of the Shublik lithologies, although they have not been observed in bedded chert (Site 18).

AREAL DISTRIBUTION

Outcrops of the Shublik Formation appear to be clustered in three areas in northern Yukon Territory and in specific tectonic elements within these areas (Fig. 9.1). In extreme northwestern Yukon, adjacent to the Alaska border, the formation occurs on the flanks of Romanzof (Figs. 9.2–9.4) and Barn uplifts and adjacent Old Crow–Babbage Depression. On the border between Yukon Territory and the District of Mackenzie, it occurs in Richardson Anticlinorium, as well as in erosional remnants in adjacent Northern Interior Platform (Peel Plateau). In the extreme southwestern part of the project area, in the Taiga–Nahoni Foldbelt, it occurs close to the apex of the deep reentrant in Ogilvie Mountains (Ogilvie Deflection).

Additional occurrences include those just outside the project area on the south flank of Monster Syncline (Green, 1972) and those on Joe Creek, Alaska, close to the international boundary (Maddren, 1912, p. 312; Mountjoy, 1967, p. 9). Many, if not all, of these occurrences may have been interconnected during the Middle and Late Triassic when the Shublik was deposited over the project area as an extensive, heterogeneous sheet of carbonate and clastic rocks, transgressive northward. The sheet was dismembered, deformed, and in large part eroded during the latest Triassic and perhaps earliest Jurassic and younger periods of epeirogeny or orogeny. What was left was a few discontinuous, commonly folded and faulted patches of the formation scattered about the northwest, east and southwest parts of the project area.

Included among these patches were beds that may not be Triassic at all. In the upper reaches of Rat River in northern Richardson Mountains, Jeletzky (1967) questionably assigned a 200 m thick, unconsolidated pebble-conglomerate, pebbly sandstone and dark grey shale assemblage to the Triassic. He named the lower conglomerate and sandstone the *Brat Creek Formation* and the upper shale the *Coaly shale division*. At its type section on Brat Creek, a small tributary to Rat River from the south, neither the base nor the top of the *Brat Creek Formation* is exposed. Nearby, on Rat River, however, the contact between the Brat Creek and the overlying Coaly shale division appears to be erosional. Moreover, the top of the Coaly shale division is covered on both Brat Creek and Rat River so that the spatial relations of the shale to overlying, poorly exposed sandstones of the Jurassic Bug Creek Group are conjectural. I favour the interpretation that the contact between the Bug Creek and the so-called Triassic assemblage is the Treeless Creek Fault (Norris, 1981a). There appears to be no question, on the other hand, that the basal contact of the Brat Creek Formation with underlying Permian sandstones is a disconformity where it is exposed in the upper reaches of Treeless Creek (Jeletzky, 1967, p. 7).

The age of the Brat Creek Formation and overlying Coaly shale division is very much in doubt in view of the strong possibility of reworking of the microflora used to date them. The presence of *Vittatina* sp., a strictly Permian genus in the Brat Creek Formation, can readily be accounted for by reworking the genus into any formation of younger age, much as Upper Devonian palynomorphs are known from the Albian Arctic Red Formation east of the Mackenzie Delta (Norris, 1981b). Moreover, the Triassic age assignment of the overlying Coaly shale division is tentative (Jeletzky, 1967, p. 9) and, on the basis of contained microflora, could range from Permian to Mesozoic (op. cit.).

Until such time as detailed studies have been carried out on the stratigraphy, contact relations and indigenous microflora of the Brat Creek Formation and the Coaly shale division, it is suggested that these units be excluded from the stratigraphic record of the Triassic of northern Yukon Territory and adjacent District of Mackenzie. Both J. Dixon and T.P. Poulton (pers. comm., 1992) consider Jeletzky's Brat Creek Formation to be the Scho Creek Member of the Murray Ridge Formation (Bug Creek Group).

In all, the Shublik Formation and its stratigraphic relationships have been studied at twenty-eight localities. They are summarized in Table 9.1, along with contact relationships, allowing a regional appreciation of the sedimentary and tectonic history of the Shublik. Mountjoy (1967) systematically described and portrayed data from many of those Shublik localities discovered in 1962. Please refer to his publication for details.

New information collected, most notably from sections on the southwest flank of British Mountains and in northern Ogilvie Mountains, has enhanced our understanding of the Middle and Late Triassic history of extreme northwestern Canada. One particularly significant section (Site 14; Table 9.1) is described below.

At Site 14, at the headwaters of Babbage River on the southwest flank of Romanzof Uplift, the stratigraphic section (117A29) extends from the Lisburne Group[1], through the Sadlerochit Group to the Shublik Formation (see Fig. 9.5 for location; Norris, 1981c). It is herein designated a principal reference section for Canada and is as follows:

Kingak(?) Formation

Covered interval in shale? for a few hundred metres.

disconformity
Shublik Formation

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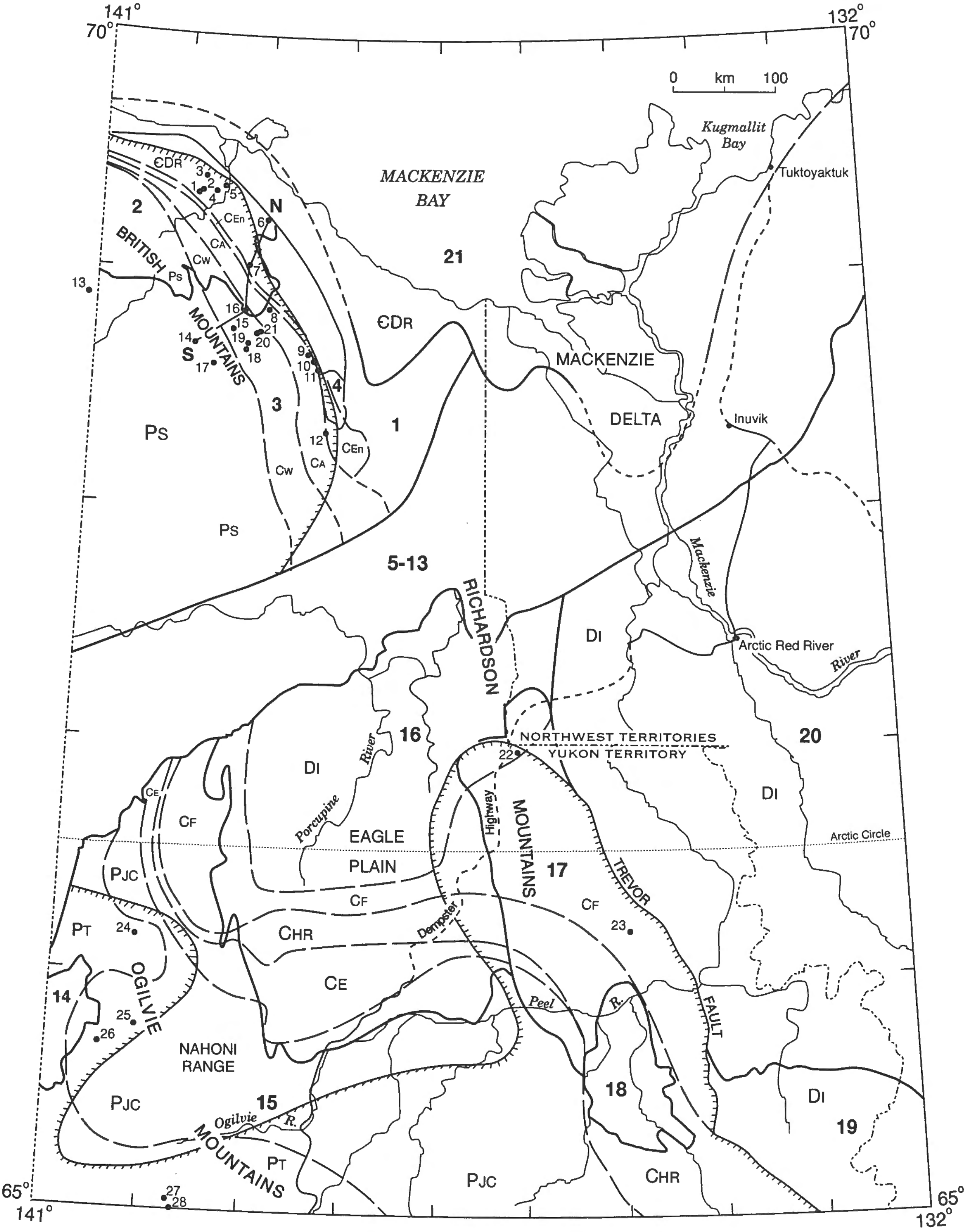
[1] For details on the stratigraphy of the Carboniferous and Permian systems, please refer to Chapter 8.



Boundary between tectonic elements (defined,approximate, assumed)

Assumed erosional limit of the Shublik Formation and equivalents

Examined sites of Shublik Formation and equivalents ●28

Tectonic elements

1	Rapid Depression
2	Romanzof Uplift
3	Old Crow-Babbage Depression
4	Barn Uplift
5-13	Aklavik Arch Complex
12	Campbell Uplift
14	Kandik Basin
15	Taiga-Nahoni Fold Belt
16	Eagle Fold Belt
17	Richardson Anticlinorium
18	Bonnet Plume Basin
19	Mackenzie Fold Belt
20	northern Interior Platform
21	Beaufort-Mackenzie Basin

Figure 9.1. *Location map for sites where the Shublik Formation and equivalents were examined in northern Yukon Territory and northwestern District of Mackenzie. Associated numbers (1–28) correspond to sites listed in Table 9.1. Assumed eastern and northern erosional limits of the Shublik Formation and equivalents, at the sub-Kingak or younger unconformities on both sides of Aklavik Arch Complex, are shown by the hatched solid lines. Corresponding contacts between subcrops of Sadlerochit* (PS), *Wahoo* (CW), *Alapah* (CA), *Endicott* (CEN), *Tahkandit and Step* (PT), *Jungle Creek* (PJC), *Ettrain* (CE), *Hart River* (CHR), *Ford Lake* (CF), *Imperial* (DI) *and Road River* (ЄDR) *formations/groups, beneath the Shublik or later formations, are shown schematically by dashed lines. The Aklavik Arch Complex is undifferentiated in order to emphasize the right-hand separation of the erosional limits of the Shublik and older formations across it. S-N is the location of the schematic stratigraphic cross-section in Figure 9.5. Tectonic elements are identified by heavy solid lines and are numbered after Norris (1983b).*

Limestone and sandstone: limestone, dark grey, argillaceous, largely as felsenmeer mixed with quartz sandstone; locally with abundant *Monotis* sp. including *M.* cf. *ochotica densestriata* Teller. According to E.T. Tozer (pers. comm., 1973), most of the monotids in this collection (GSC loc. C–18167) are Late Norian (late Late Triassic) in age. Thickness: 5 m (approximate)

disconformity

Sadlerochit Group
Ivishak(?) Formation

Sandstone: quartz, slightly calcareous, medium to dark grey, fine grained, pale yellowish grey weathering; and siltstone: slightly calcareous, light grey weathering; with sparse impressions of *Zoophycos*-like markings and rare, poorly preserved pelecypods (GSC loc. C–11872). Thickness: 8 m

Covered interval (shale?). Thickness: 120 m (estimate)

Total thickness of Ivishak(?) Formation: 128 m (estimate)

Echooka Formation

Limestone: medium grey, very finely crystalline, pale orange weathering, forming a dip slope. Thickness: 8 m

Sandstone: quartz, slightly calcareous, dark grey, very fine grained, massive, brown weathering, abundantly fossiliferous (GSC loc. C–11868). According to J.B. Waterhouse (pers. comm., 1972), this collection is Kungurian (late Early Permian). Thickness: 6.4 m

Limestone: fetid, medium grey mottled with medium brownish grey, massive, brown weathering (GSC loc. C–13852). Thickness: 2.4 m

Sandstone: quartz, noncalcareous, dark grey, very fine grained, massive, weathering dark brownish grey with pale red patches (GSC loc. C–11869). According to J.B. Waterhouse (pers. comm., 1972), this collection is Kungurian (late Early Permian). Thickness 6.4 m

Covered interval. Thickness: 30 m (approximate)

Mudstone: noncalcareous, dark grey, chunky to chippy weathering. This unit is best exposed between 14 and 18 m above its base. GSC loc. C–138531 is between 15.8 and 16.5 m above the base of the unit. Thickness: 36.6 m (approximate)

Covered interval. Frost boils show black, chippy shale toward the top of the unit. Thickness: 110 m (approximate)

Total thickness of Echooka Formation: 199.8 m (approximate) disconformity

disconformity

Lisburne Group
Wahoo Formation

Top beds are limestone, medium light grey, finely crystalline, very pale orange weathering (GSC loc. C–138530). Uppermost beds of the Wahoo Formation, 15 km to the northwest, are Morrowan to Atokan (early Late Carboniferous) (Mamet and Mason, 1970, p. 559; GSC Section 117A3).

End of Section

Figure 9.2. *Pale orange weathering limestone of the Shublik Formation (TRS) resting unconformably upon black, cherty shale of the Road River Formation (ЄDR) on the north flank of Romanzof Uplift at Site 5, immediately west of Firth River. Note that the light weathering Shublik is dismembered because of Early Tertiary Laramide deformation. The Road River here is late Early Devonian (Emsian) in age according to T.T. Uyeno (pers. comm., 1985). The Shublik is late Late Triassic (Norian) according to E.T. Tozer (pers. comm., 1973). ISPG photo 2421-206.*

The Shublik Formation is the youngest stratigraphic unit of the Triassic System in northwestern Canada. It is latest Triassic (Late Norian) in age at Site 14, and appears to be coeval in part with the Karen Creek Sandstone (Detterman et al., 1975) in northeastern Alaska. Its thickness (about 5 m) indicates, moreover, that this locality is near the northeastern erosional limit of the formation as a result of truncation at the sub-Jurassic (sub-Kingak) disconformity.

The Echooka Formation at Site 14 is Kungurian (late Early Permian) and appears to be lithologically similar to the type section of the Echooka on Kemik Creek in northeastern Alaska as well as to the Joe Creek section (Site 13). There is little doubt, therefore, about the presence of the lower part of the Permian Sadlerochit Group on the south flank of Romanzof Uplift on both sides of the international boundary.

The presence of Lower Triassic rocks east of the Alaska border has not been proved. The 128 m interval of shale (?) and sandstone occurring between the Echooka and the Shublik at Site 14 is homotaxial with the Ivishak Formation. In the absence of diagnostic fossils, it is tentatively assigned to the Ivishak (Fig. 9.5). On the other hand, the *Zoophycos*-like markings observed in the 8 m sandstone bed (GSC loc. C-11872) described above at the top of the interval is suggestive, although not diagnostic, of a Permian rather than a Triassic age. The Ivishak may also be present on Joe Creek as suggested by Mountjoy (1967, fig. 3).

At the extreme southeast termination of Romanzof Uplift, a second important section of the Shublik (Site 16, Section 117A37) was discovered on Gravel Creek close to its junction with Trail River (Figs. 9.1, 9.5; Norris, 1981c). The importance of the section lies in the disconformable relationships of the Shublik with contiguous formations. The Shublik at this locality appears to rest disconformably upon the Carboniferous Lisburne Group such that the Permian–

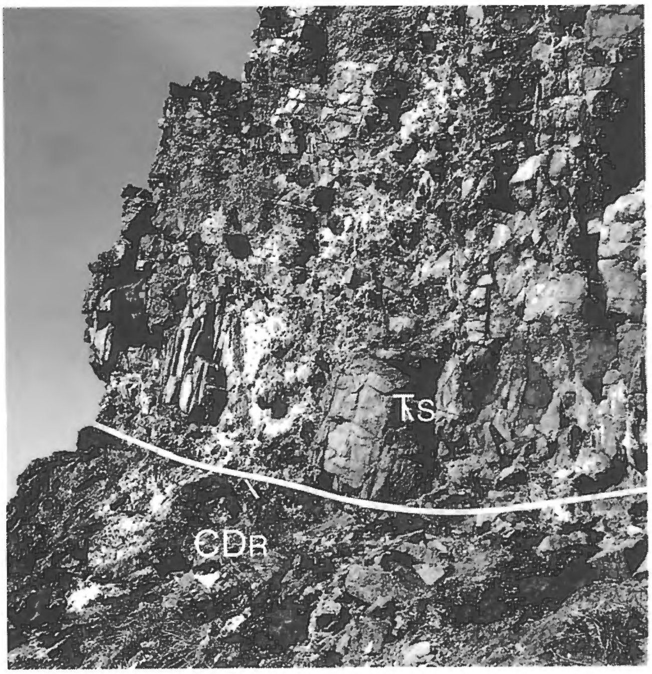


Figure 9.3. *Angular unconformity between the Road River (ꞒDR) and Shublik (TRs) formations at Site 5 on lower Firth River. The point of hammer is at the unconformity and the handle indicates the direction and magnitude of dip of Road River strata. GSC photo 3-10-72.*

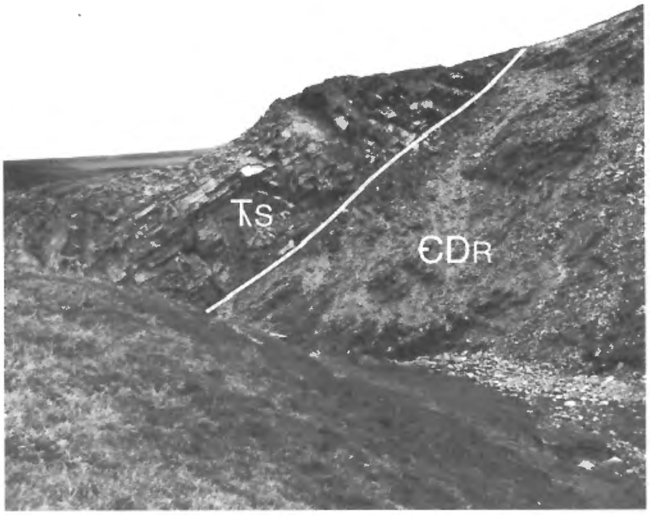


Figure 9.4. *Locally disconformable contact between grey limestone and conglomerate of the Upper Triassic Shublik Formation (TRs) and interbedded pale red and medium grey, slaty argillite of the lower Paleozoic Road River(?) Formation (ꞒDR) at Site 4 on the north flank of Romanzof Uplift. GSC photo 5-5-1971.*

Triassic? Sadlerochit Group is absent (in contrast with Site 14). Moreover, the Shublik appears to be overlain disconformably by the Jurassic Kingak Formation, in harmony with the regional relationship between basal Kingak and underlying formations.

LITHOLOGIC VARIATIONS

The Shublik Formation in Canada is characterized by two distinct facies, one representing nearshore, inner shelf depositional environments, and the other, deeper water, organic-rich, outer shelf facies. The former is confined to the northern and eastern exposures in British, Barn and Richardson mountains and Peel Plateau, and the latter to the southwestern part of the project area in Ogilvie Mountains at the headwaters of Ogilvie River. Middle and Late Triassic shale and limestone at the base of the Glenn Shale (Brabb, 1969) in adjacent Alaska are considered to be the Shublik Formation.

A noteworthy characteristic of the nearshore facies of the Shublik is its heterogeneity, with rapid changes in facies both vertically in any given section and laterally from one section to another (Table 9.1). The basal conglomerate and conglomeratic limestone changes to limestone (Figs. 9.2, 9.3), sandstone and siltstone, or perhaps chert (Fig. 9.6), from one exposure of the formation to another, so that it is not yet possible to map the continuity of the facies along or across strike in the northern part of the area. Correspondingly, it is not possible to subdivide the formation into members as has been done in adjacent northeastern Alaska (Detterman et al., 1975). There is, for example, no Clay shale member at the top of the formation similar to that which is present at the reference section for the Shublik on Fire Creek, approximately 160 km west of the Alaska border. Moreover, coquinas rich in pelagic monotid and halobiid bivalves occur at any stratigraphic level. Neither glauconite nor phosphate has been reported from this nearshore facies in northern Yukon Territory although both are reported from equivalent beds in northern Alaska (Parrish, 1987, p. 392).

Across the Aklavik Arch Complex in the Richardson Mountains, light grey, shelly, calcareous siltstone (Site 22; Fig. 9.1) and light grey, skeletal limestone (Site 23) make up the Shublik Formation. The former rocks rest with angular unconformity on

Upper Devonian Imperial Formation and the latter disconformably upon the Upper Devonian and Lower Carboniferous Ford Lake Shale (Fig. 9.1).

In the southwestern part of the project area, black, sooty, argillaceous limestone, calcareous shale and dark grey siltstone predominate in the deeper water facies. Monotid and halobiid coquinas prevail here as well. They document the time-transgressive nature of the Shublik because the lowest beds in the formation get progressively younger across the area toward the north to northeast. Even in the deeper water facies there are marked changes laterally from shale to limestone to siltstone, reflecting local changes in depositional environments.

THICKNESS VARIATIONS AND REGIONAL TRENDS

The thickness of the Shublik Formation in northern Yukon Territory increases progressively southwest-

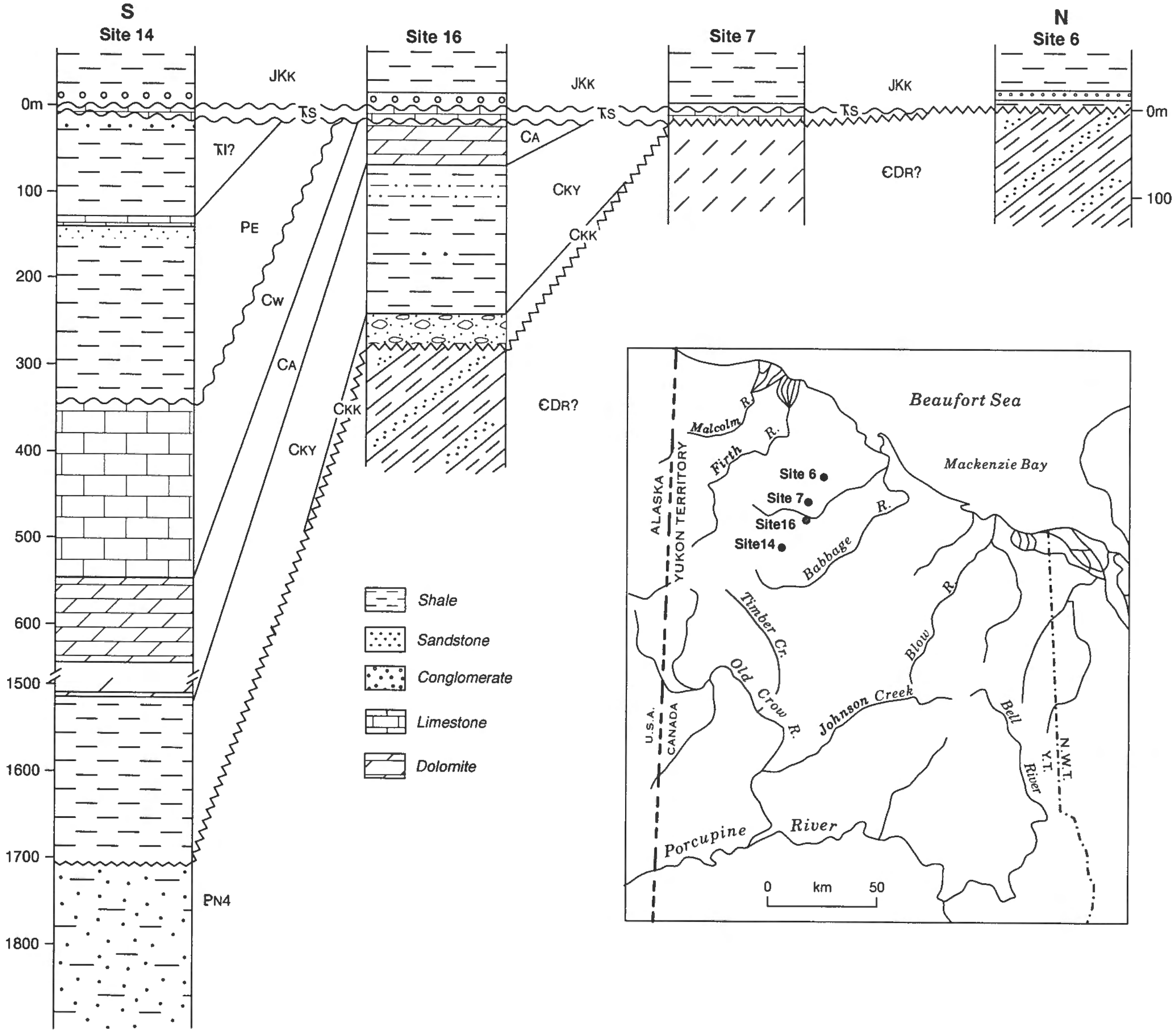


Figure 9.5. Schematic stratigraphic cross-section (S-N on Fig. 9.1) portraying the overstepping relationship of the Shublik Formation onto progressively older rocks northward, in the direction of a late Paleozoic–early Mesozoic land mass in the position of the Holocene continental shelf of southern Beaufort Sea. Symbols for rock units are as follows: PN4, *Neruokpuk Formation;* ЄDR, *Road River Formation;* CKK, *Kekiktuk Formation;* CKY *Kayak Formation;* CA, *Alapah Formation;* CW, *Wahoo Formation;* PE, *Echooka Formation;* ŦI, *Ivishak Formation;* ŦS, *Shublik Formation;* JKK, *Kingak Formation.*

Table 9.1

Sites (1–28) where the Shublik Formation and its contact relationships were examined in northern Yukon Territory and northwestern District of Mackenzie, with supporting information. Disconformities are shown as a slash (/) and angular unconformities by a wavy line (~).

Site	Stn.	Section	GSC loc.(s)	Age*	Rept.	Thick. (m)	Lithology	Location	Air photo	Setting
1	175MJ	117D1	52794–96	Tr?lN	Tr–8–1963ETT	86.9	ls, slst, cgl.	u. Loney Ck.	A15462–13	JKk / TRs ~ ЄDr?
2	162NC	—	C6645	?lTr	Tr–6–1970ETT	—	ss, sh	u. Loney Ck.	A13140–104	JKk / TRs ~ ЄDr?
3	573NC	—	C11857	?lTr	Tr–3–1972ETT	—	ls	l. Loney Ck.	A15462–13	JKk / TRs ~ ЄDr?
4	891NC	—	C11878, 79	Trlm–lN	Tr–3–1972ETT	22.6	ls, cgl	l. Loney Ck.	A13140–104	JKk / TRs ~ ЄDr
5	211NC	—	C18159	TrlN	Tr–5–1973ETT	18.6	ls, cgl	l. Firth R.	A13751–116	JKk / TRs ~ ЄDr
6	890NC	—	C138577	—	—	0	—	Spring R.	A14361–100	JKk ~ ЄDr?
7	499NC	—	C11854	Tr?lm–lN	Tr–3–1972ETT	—	ls, cgl	l. Crow R.	A13470–153	JKk? / TRs ~ ЄDr?
8	503NC	117A13	C11855	Trlm–lN	Tr–3–1972ETT	69.5	ss	Philip Ck.	A13470–127	JKk / TRs Ca?
9	227NC	117A25	55373	TrlN	Mountjoy, 1967	≥72	ls, sh, ss	Mt. Welcome	A13383–138	JKk / TRs / Ca?
10	453NC	—	C6123	Tre–mN	Tr–5–1976ETT	—	**	Barn Mts.	A13383–137	JKk / TRs / Cl
11	565NC	117A7	C6150–53	TrlN	Tr–7–1970ETT	13.4	dol, ls	Barn Mts.	A13383–137	JKk / TRs / Cky
12	819NC	—	C11860	Trlm–lN	Tr–3–1972ETT	—	slst, ss	Barn Mts.	A14406–32	JKk / TRs / Cky
13	257NB	117B1	54723	TrN	Mountjoy, 1967	159	ss	Joe Ck., Ak.	A13138–168	? TRs / Pe?
14	930NC	117A29	C18167	TrlN	Tr–5–1973ETT	≥5	ss, ls	British Mts.	A13140–93	? TRs / TRl?
15	174NC	—	55143	Tr?N	Tr–8–1963ETT	—	ss	u. Gravel Ck.	A13751–91	JKk / TRs / Cl
16	988NC	117A37	C27122, 23	TrmN	Tr–1–1974ETT	16	ls	l. Gravel Ck.	A13751–93	JKk / TRs / Cl
17	843NC	—	C11867	TrmN	Tr–3–1972ETT	—	slst	u. Babbage R.	A13751–130	JKk / TRs / Ps
18	1000NC	—	C27136	—	1–BLM–1976	≥9	cht, cgl	u. Babbage R.	A13470–160	JKk / TRs? / Cw
19	15NEU	117A21	53320, 22	Tr?lN	Tr–8–1963ETT	112	ss, sh	u. Babbage R.	A13470–159	JKk / TRs / Cl?
20	14NEU	117A20	53302	Tr?lN	Tr–8–1963ETT	55.8	ls, sh	u. Babbage R.	A13470–159	JKk / TRs / Cl
21	841NC	—	C11864	Trlm–lN	Tr–3–1972ETT	—	ls	u. Babbage R.	A13470–124	JKk / TRs ?
22	239MJ	116I8	52729	?lTr	Mountjoy, 1967	26.8	ss, ls, slst	u. Vittrekwa R.	A14368–36	JKnb / TRs ~ Di
23	34NC	—	55142	?lTr	Tr–8–1963ETT	—	ls, ss	Peel Plateau	A13753–23	Kmg / TRs / Cf
24	671NC	116K1	86973	TrlN	Tr–3–1971ETT	≥7	sh	u. Fishing Br.	A13140–176	JKk / TRs / Pt
25	696NC	—	C6176	TrL	Tr–7–1970ETT	—	ls, slst	u. Fishing Ck.	A13140–182	JKk / TRs / Pjc
26	694NC	116F14	C45969	Tr?L	Tr–9–1975ETT	11.6	ls, cht	Kandik Basin	A13134–17	JKk / TRs / Pjc
27	667NC	—	C6169	TrmN	Tr–1–1976ETT	—	slst, ls, cgl	u. Ogilvie R.	A13135–198	Kbi / TRs / Pt
28	623NC	—	47137	TrN	Tr–5–1961ETT	—	sh, slst	u. Ogilvie R.	A13135–198	Kbi / TRs / Pt?

*see Norris (1976, p. 263–265) for explanation of time symbols
**field notes lost in Margaret Lake fire, August, 1970

ward. It ranges from zero at the erosional feather edge of the formation on the north flank of British and Barn Mountains, to 22.6 m on lower Loney Creek, to 86.9 m on upper Loney Creek (Section 117D1), to a maximum of about 160 m on the southwest flank of British Mountains in the vicinity of Joe Creek (Table 9.1). In the southwest corner of the area, however, the formation is commonly acutely deformed and poorly exposed so that it is not possible to determine accurately the depositional thickness of the unit, let alone thickness variations due to erosion at the sub-Jurassic unconformity. Mountjoy (1967, p. 17) assigned a covered interval of 238 m to the Shublik on the north flank of Monster syncline along the southern boundary of the project area. Moreover, he reported (op. cit., p. 16) "close to 1,000 feet of tightly folded and faulted beds" of typical basinal Shublik lithology on the south flank.

AGE, FAUNAS AND CORRELATION

Abundant and generally well preserved marine faunas collected from the Shublik Formation in the project area range in age from late Middle Triassic (Ladinian) to late Late Triassic (Norian). The oldest fauna was found in the extreme southwest corner of the project area in western Ogilvie Mountains at the headwaters of Fishing Creek (Fig. 9.1, Site 25, GSC loc. C-6176). There, abundant *Daonella degeeri* Bochum and *Ptychites nanuk* Tozer were recovered from dark grey, finely crystalline limestone with dark grey, argillaceous

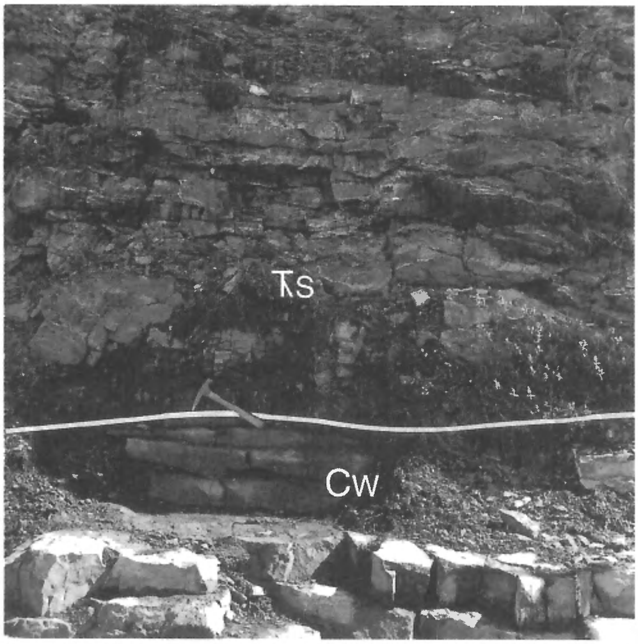


Figure 9.6. *Unconformable contact between dolomitic limestone of the Wahoo Formation* (Cw) *and chert breccia-conglomerate of the basal Shublik Formation(?)* (TRs) *at Site 18 on upper Babbage River, 2 km upstream from its junction with Cottonwood Creek. The Wahoo Formation here is early Late Carboniferous (Bashkirian, Zone 20 or 21) according to B.L. Mamet (pers. comm., 1976); Shublik Formation(?) is undated. The point of the hammer is on the disconformity. GSC loc. C–55423. ISPG photo 662-79.*

siltstone interbeds. According to E.T. Tozer (pers. comm., 1970), the fauna is Ladinian in age. The youngest faunas, on the other hand, were found generally at the northern outcrop limit of the Shublik on the north flank of British and Barn Mountains. On lower Loney Creek on the north flank of British Mountains (Site 5), *Monotis* cf. *M. ochotica densestriata* Teller, recovered from dark grey to black, argillaceous limestone, indicates a Late Norian age for the Shublik. Similarly, at Mount Welcome, on the north flank of Barn Mountains (Site 9), the presence of *Monotis ochotica* confirms a Late Triassic, Norian age for the Shublik close to its cutoff at the sub-Jurassic unconformity. No vertebrate fossils have yet been reported from the Shublik in Canada, although they are common in it in Alaska (Parrish, 1987, p. 394).

The Shublik Formation in Canada is directly correlative with its counterpart across northern Alaska. Its heterogeneous assemblage of dark grey limestone, conglomeratic limestone, argillaceous limestone, siltstone and shale, and its richly fossiliferous horizons and interbeds make it a distinct formation, unique to the Middle and Upper Triassic Series of northern Yukon Territory. Its Late Norian age at its northern extremity in Yukon Territory, moreover, would indicate that it is in part coeval with the Karen Creek Sandstone (Detterman et al., 1975) of northeastern Alaska. However, there is no dark grey sandstone with *Monotis ochotica ochotica* Keyserling intervening between the Shublik and the Kingak formations in Canada.

CONTACT RELATIONS AND OVERSTEP

Reappraisal of the localities at which the Shublik has been examined in the project area northwest of the Aklavik Arch Complex reveals a systematic truncation, from southwest to northeast, of Permian and Lower Triassic(?) Sadlerochit Group, Lower and Upper Carboniferous Lisburne Group, Lower Carboniferous Endicott Group and lower and middle Paleozoic Road River Formation (Fig. 9.1). This overstepping relationship is dramatically displayed by four localities representing a south to north transect of Romanzof Uplift (Fig. 9.5).

On the southwest flank of the uplift at the headwaters of Timber Creek, a full section (Site 14; Section 117A29) of the Lower Carboniferous Endicott Group (170 m), resting on the Neruokpuk Formation, is overlain by about 1200 m of the Lisburne Group and, in turn, by about 200 m of the Echooka, 128 m of the Ivishak(?), and 5 m (exposed) of the Shublik Formation (see section described above). Twenty-five kilometres to the northeast, close to the termination of the Romanzof Uplift, at the junction of Trail River and Gravel Creek (Site 16; Section 117A37), the sub-Shublik unconformity has cut deeply into the upper Paleozoic section. The Sadlerochit Group and Wahoo Formation appear to be absent, and only 53 m of the Alapah Formation remains above the Endicott Group. Relative to the Timber Creek section, about 1500 m of Carboniferous and Permian strata have been removed in post-Kungurian, pre-Norian times. Another 15 km due north, on the immediate northeast flank of Romanzof Uplift between Spring and Crow rivers (Site 7), about 15 m of Shublik Formation rest upon slaty argillites and quartzites of the lower Paleozoic Road River(?) Formation. Relative to the Gravel Creek section, another 260 m of Lisburne and Endicott groups plus an unknown amount of Road River(?) Formation have been eroded from the section. And 24 km east-northeast of there (Site 6), also on the northeast flank of Romanzof Uplift, Jurassic Kingak Formation overlies acutely deformed Road River(?) Formation (Figs. 9.5, 9.7) with angular unconformity. In addition to an unknown amount of the lower Paleozoic Road River(?) Formation, more than 1500 m

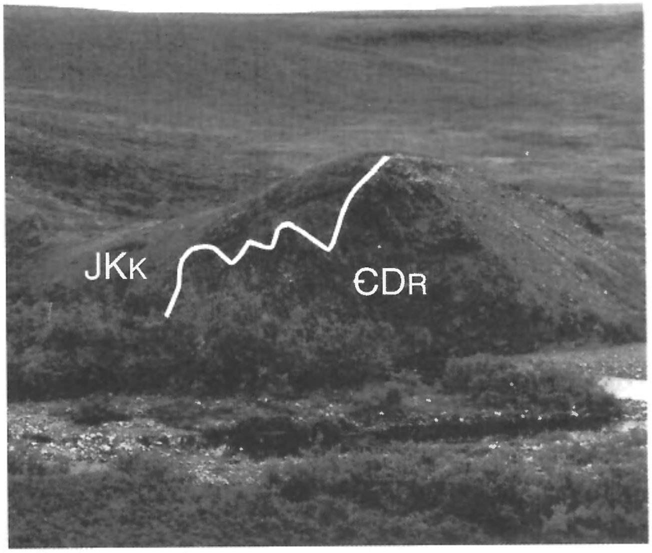


Figure 9.7. *Angular unconformity between slaty argillites and quartzites of the Road River(?) Formation (ЄDR) and the Jura-Cretaceous Kingak shale (JKK) at Site 6 on the northeast flank of Romanzof Uplift near Spring River, northern Yukon Territory.*

of upper Paleozoic and Lower Triassic(?) formations observed on the southwest flank of the uplift have been removed at the sub-Shublik unconformity.

Southeast of the Aklavik Arch Complex, the Shublik appears to demonstrate the same systematic northeastward overstepping onto progressively older formations as noted north of the arch, although stratigraphic control is limited. In the extreme southwest corner of the project area, at the headwaters of the Ogilvie River, the Shublik rests disconformably upon the Permian Jungle Creek (Echooka equivalent; Sites 25 and 26) and Tahkandit (Sites 27 and 28) formations. Well to the east, in Richardson Mountains and adjacent Peel Plateau, it rests disconformably upon Upper Devonian Imperial Formation and Upper Devonian and Lower Carboniferous Ford Lake Formation (Sites 22 and 23, respectively).

PALEOGEOGRAPHIC AND TECTONIC INTERPRETATION

The thick succession of upper Paleozoic and Lower Triassic(?) formations beneath the Shublik in northern Yukon Territory may have been in the form of a simple, southwest-dipping homocline that was uplifted and erosionally truncated in the late Early or early Middle Triassic. Northward truncation of the thin, but regionally persistent Shublik Formation at the sub-Jurassic disconformity, on the other hand, was much less abrupt.

From the northwest flank of the Aklavik Arch Complex to the Alaska border, the erosional limits of the Endicott Group, the Alapah and Wahoo formations, and the Sadlerochit Group follow curvilinear traces trending northwest on the sub-Shublik unconformity (Fig. 9.1). These traces are subparallel to the structural grain of Barn and Romanzof uplifts. Moreover, from southeast to northwest they converge markedly and call attention to increasingly abrupt truncation of all these upper Paleozoic rock units comprising the homocline near the Alaska border. They suggest the possibility of some form of structurally controlled, mid-Triassic, northeast-facing escarpment, coinciding with the crest of the Cenozoic Romanzof Uplift. The Shublik transgressed the escarpment toward the northeast in the Late Triassic.

Southeast of the Aklavik Arch Complex, the curvilinear traces of the eastern and northern limits of the Ford Lake, Hart River, Ettrain, Jungle Creek and Tahkandit formations at the sub-Shublik disconformity again appear generally to follow the structural grain of the Cenozoic uplifts with which they are associated. They trend northwest from the Mackenzie Mountains, swing west across southern Eagle Plain and turn north, parallel to the strike of the northern Ogilvies, before terminating along the southeast flank of the Aklavik Arch Complex. There they undergo a right-hand separation of about 130 km from their counterparts on the opposite flank of the arch.

The presumed eastern and northern erosional limits of the Shublik, at the sub-Jurassic disconformity in Canada (Fig. 9.1), also follow approximately the curvilinear structural grain of the Cenozoic uplifts comprising the Cordilleran Orogen. The trace of this cutoff trends southeast along the north flank of Romanzof Uplift, then south over Barn Uplift, terminating at the northwest flank of the Aklavik Arch Complex. There, it is separated right-hand by about 200 km from an undetermined point west of the Alaska border before continuing generally eastward into Canada, then northward and eastward over Richardson Anticlinorium to where the pre-Cretaceous Trevor Fault appears to define the eastern limit of the Shublik.

There are, therefore, three fundamental features of sedimentation and tectonism in the northern Cordillera, illustrated by: the facies distribution of the Shublik Formation, the traces of the northern and eastern erosional limits of rock units beneath the

Shublik, and the eastern and northern limits of the Shublik at the sub-Jurassic disconformity. First, the nearshore, shallow water facies trends of the Shublik and their eastern and northern erosional limits, as well as the trends and limits of those formations it oversteps, all tend to follow the curvilinear trend of the structural grain of the Cenozoic Cordilleran Orogen. In turn, they delineate the fundamental, ancient and persistent shape of the Cordilleran miogeocline (Norris, 1972, p. 642). Second, the Shublik Formation, as well as the Paleozoic units it oversteps, appears to have been deposited on top of the Aklavik Arch Complex and then removed from it in the Early Jurassic or later. Third, the right-hand separation of the panels of Upper Paleozoic formations of between 100 and 200 km from one side of the Aklavik Arch Complex to the other, as well as of the concordant separation of the panels of Shublik Formation, could be due to the intital shape of the ancestral margin of the miogeocline. On the other hand, they could be due to a significant horizontal component of dextral slip within or on the flanks of the Aklavik Arch Complex in post-Shublik, pre-Kingak time, or they could be due to a combination of both initial shape and faulting.

The Kaltag Fault defines the northwest flank of the Aklavik Arch Complex in northern Yukon Territory. It is interpreted as having a dextral offset of about 100 km in the vicinity of the Alaska border (Norris, 1983a; 1987; Chapter 3), consistent in magnitude and sense of separation with those of the panels of Triassic and older rocks across the arch. T.P. Poulton (Chapter 10) correctly points out that the Jurassic rocks do not permit any conclusive statement regarding displacement on the Kaltag Fault in this structural position.

DEPOSITIONAL ENVIRONMENTS

The depositional model perceived for the Shublik Formation is one of sedimentation near and seaward of a curvilinear shoreline that migrated north to northeastward across the area in mid- to Late Triassic time. Thus, in any one stratigraphic section, the outer shelf facies would overlie the inner shelf, with the latter being deposited on progressively older formations northward. Moreover, the disconformable nature of the contact between the Shublik and underlying rocks would suggest that the pre-Shublik hiatus (ca. 10 Ma) embraced a time of gentle, regional, differential uplift and peneplanation. Depending upon the presence of the Ivishak Formation, the pre-Shublik is the only hiatus within which a whole Phanerozoic Series (Lower Triassic, Scythian) may be missing throughout the project area (Norris, 1983b).

The sub-Shublik disconformity, therefore, is presumed to have been one of low relief, so that as systematic, northward transgression and flooding took place, whether by epeirogeny or eustasy, there were pronounced as well as rapid lateral and vertical shifts in biotopes and lithotopes in the Middle and Late Triassic sea of northern Yukon Territory and the adjacent continental shelf. The abrupt facies changes from pebble-conglomerates to fragmental limestone to siltstone and sandstone in the Shublik on the north flank of Romanzof and Barn uplifts support this interpretation. Moreover, the pelagic faunas contributed simultaneously to the fossil record of coeval inner and outer shelf facies, so that the same monotid and halobiid assemblages occur both close to shore and basinward (compare Sites 5 and 24, Table 9.1).

The lithology and geochemistry of the Shublik Formation indicate well oxygenated, low-energy conditions nearshore, favorable to the burial and preservation of thin-shelled bivalves (Parrish, 1987, p. 394). Farther offshore (southwestward), the facies are fine grained and organic rich. Dark grey, argillaceous limestone, calcareous mudstone and siltstone suggest a northeast to southwest gradient like that described by Parrish (1987, p. 393) for the same units in northern Alaska, with decreasing oxygen but with plentiful food supply. High biologic activity is indicated by the extreme abundance of *Monotis* and *Halobia*. The prevalence of thick, coquinoid beds, moreover, would suggest widespread coastal upwelling zones of anoxic bottom waters that broke the surface and resulted in mass kills through suffocation (op. cit., p. 394). Storms may have helped to concentrate as well as disperse the coquinas.

The sub-Kingak disconformity was also one of low relief. The Kingak appears to have blanketed the region and, so far as is known, only parts of the Rhaetian and Hettangian stages may be missing between the Shublik and the Kingak over much of the area. Exceptions appear to be parts of the Aklavik Arch Complex and northern Taiga–Nahoni Foldbelt, where Hettangian Kingak is interpreted to rest upon the Shublik (Chapter 10, Table 10.1). Most if not all of the project area must have been uplifted regionally, peneplaned and submerged rather quickly about the time of the Triassic–Jurassic boundary.

HYDROCARBON AND MINERAL POTENTIAL

The overstepping of the Shublik onto progressively older formations northeastward, as well as the erosional truncation of the Shublik at the sub-Jurassic unconformity, means that the southeastward extensions of the Permian and Triassic reservoirs at Prudhoe Bay do not reach into mainland Canada (Norris, 1974, p. 35). Moreover, it would appear unlikely that they would be found on the continental shelf, although that consideration is academic; if present, they would be well beyond present drilling technology. In addition, geochemical analysis of the Shublik by the U.S. Geological Survey (reported by Parrish, 1987, p. 392), indicates that the formation is regionally thermally overmature.

In contrast with northeastern Alaska, the potential of the Shublik in Canada as a source of phosphate is not encouraging. Vivianite-enriched, septarian ironstone nodules are known only from the upper Shublik at the eastern end of Monster Syncline (Site 27). No bedded phosphate has been reported from the project area. It cannot be ruled out, however, until more detailed field and petrographic investigations have been conducted.

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Unnamed Permian clastics overlain disconformably by the Jurassic Bug Creek Group to the top of Murray Ridge at section 116P6 immediately east of White Mountains. GSC photo 1122-15.

CHAPTER 10

JURASSIC

T.P. Poulton

Poulton, T.P., 1996. Jurassic. In The Geology, Mineral and Hydrocarbon potential of Northern Yukon Territory and Northwestern District of Mackenzie. Geological Survey of Canada, Bulletin 422, p. 267–299.

Abstract

The Jurassic rocks of northern Yukon and westernmost Northwest Territories are entirely marine sedimentary strata deposited in a somewhat unstable epicratonic shelf setting at what was then the northwestern corner of the North American continent. The eastern and southeastern facies comprise a series of superposed sandstone and shale sequences which are thicker, more argillaceous, and more complete (in terms of the time they represent) to the west and northwest. They comprise the Bug Creek Group, and the Husky and Porcupine River formations. Disconformities between these sequences increase in number and magnitude toward the stable craton to the southeast and east. Thickness and facies trends suggest point sources for the introduction of sediment supply to the marine shelf environment, and redistribution on the shelf by marine currents. The sediment sources migrated southward through the Jurassic, in association with increased southward and southeastward episodic transgression of the craton. Equivalent strata to the west and northwest are in an entirely siltstone and shale facies, the Kingak Formation. Every stage of the Jurassic, and 33 fossil zones, are indicated by diagnostic ammonites or bivalves.

Résumé

Toutes les roches jurassiques du nord du Yukon et de l'extrême ouest des Territoires du Nord-Ouest sont des couches sédimentaires d'origine marines déposées sur une plate-forme épicratonique quelque peu instable qui correspondait alors au coin nord-ouest du continent nord-américain. Les faciès est et sud-est comprennent une série de séquences de grès et de shale superposées qui deviennent plus épaisses, plus argileuses et plus complètes (par rapport à l'échelle chronostratigraphique qu'elles représentent) vers l'ouest et le nord-ouest. Elles englobent le Groupe de Bug Creek et les formations de Husky et de Porcupine River. Les discordances entre ces séquences augmentent en nombre et en ampleur vers le craton stable au sud-est et à l'est. L'épaisseur et les directions des faciès incitent à proposer des sources ponctuelles pour les sédiments déposés dans le milieu de plate-forme continentale marine et redistribués sur la plate-forme par les courants marins. Les sources sédimentaires ont migré vers le sud pendant le Jurassique, concurremment à une augmentation vers le sud et le sud-est de la transgression épisodique du craton. Les couches équivalentes vers l'ouest et le nord-ouest sont contenues dans un faciès entièrement composé de siltstone et de shale, soit la Formation de Kingak. Des ammonites ou des bivalves indicateurs permettent de localiser chaque étage du Jurassique et de déterminer 33 zones fossilifères.

INTRODUCTION

This chapter provides a brief summary of our knowledge of the Jurassic rocks and a synthesis of the paleogeographic, tectonic, and sedimentologic conditions of the basin in which they were deposited. Most of the detailed data have been published by several authors; only summaries and references to those previous reports are given here. The paleogeographic interpretations and their tectonic implications differ considerably from those of Jeletzky (1975, 1980), another major worker in the same area. Their documentation and a discussion of the different interpretations are given in previous papers (Poulton et al., 1982; Poulton, 1982) and are not repeated in detail in this report.

The first indication of the presence of Jurassic rocks was in the form of fossils in the possession of Hudson's Bay Company chief factor George Barnston, which were discovered by H.Y. Hind, leader of the Assiniboine and Saskatchewan Exploring Expedition of the Northwest Territory, under instruction from the provincial secretary of Canada. The single sample contained two ammonite species which were described as new by F.B. Meek (1859), who mistakenly thought them to be Cretaceous, although he recognized their Jurassic affinities. It is presumed that trappers carried the sample to the trading post in the Mackenzie River valley, from its probable source on the banks of the Porcupine River at Salmon Cache Canyon.

The next Jurassic fossils from the area were collected along Porcupine River by R.G. McConnell in 1888. They also were misidentified as Cretaceous by J.F. Whiteaves (McConnell, 1891, p. 123D, 124D). Jeletzky (1960, Correlation chart) recognized the Jurassic age of McConnell's 'Sandstone and quartzite series' and later named them the Porcupine River Formation (Jeletzky, 1977). Frebold (1961, p. 6, 10) described the ammonites collected by McConnell from underlying shales as Jurassic species. J.J. O'Neill collected ammonites from the lower part of Firth River in 1914, which S.S. Buckman recognized as Callovian (O'Neill, 1924, p. 14A–15A). Subsequent work has resulted in the accumulation of large numbers of fossil collections, described stratigraphic sections, and several syntheses of the regional framework. Every stage of the Jurassic is now recognized by marine fossils. The most significant sources of new data have been field and paleontological studies by H. Frebold, J.A. Jeletzky, D.K. Norris, F.G. Young, J. Dixon and T.P. Poulton. In addition to all these workers, numerous petroleum exploration geologists and E.W. Bamber and E.W. Mountjoy provided samples and unpublished information to the GSC. J.A. Jeletzky identified most of the *Buchia* species which are reported here. J.H. Callomon was involved in the fieldwork during two summers and his contributions to both the description of stratigraphic sections and the biostratigraphic framework are significant.

REGIONAL GEOLOGIC SETTING

Jurassic rocks are distributed widely in the outcrop and subsurface of northern Yukon and adjacent Northwest Territories (Fig. 10.1). They unconformably overlie Proterozoic through Upper Triassic rocks from place to place, indicating that the basin in which they were deposited developed after a latest Triassic period of uplift and erosion. The thickness and lithologic variations in the Lower Jurassic strata indicate deposition on a surface with only minor local relief. The strata comprise a series of superimposed clastic wedges that, on a regional scale, become thicker, proportionately finer grained, and more complete in terms of the record preserved to the west and northwest, away from the exposed North American craton from which they were derived (Fig. 10.2).

The Jurassic succession is overlain by a superficially similar series of Cretaceous sandstones, siltstones and shales. They contain the record of rifting related to the opening of the Canada Basin (Dixon and Dietrich, 1990; Embry and Dixon, 1990) and the Cordilleran and Brooks Range orogeny, with a change of dominant sediment source to the west and southwest (e.g., Young, 1973; Norris, 1974, p. 33–34; Young et al., 1976; Balkwill et al., 1983).

The basin lying northwest of the craton in Jurassic time was called the Beaufort–Mackenzie Basin by Young et al. (1976), who treated the Jurassic history of the area as the early part of a continuous but complicated evolution of the area through Tertiary time. Balkwill et al. (1983), however, called its Jurassic to Neocomian manifestation the Brooks–Mackenzie Basin (Fig. 10.3), emphasizing the major tectonic reconfiguration of the entire Arctic North America region in Hauterivian through Aptian time, and the apparent essential integrity of the Jurassic and earliest Cretaceous basins of the northern Yukon with those of northern Alaska.

Four major coarsening-upward, progradational sequences are recognized in the arenaceous, southeastern basin-margin succession. At a more detailed scale, interdigitation of arenaceous and argillaceous units in the basin-marginal areas records numerous transgressive and regressive episodes in an overall subsiding shelf regime. The basin margin structure was complicated by local faults and a series of uplifts and depressions, at least some of which were fault-bounded (Fig. 10.4). They were active at different times during the Jurassic.

The three lower major sequences in the southeastern basin-margin succession comprise the Bug Creek Group (Table 10.1). It was named the Bug Creek Formation by Jeletzky (1967) and was raised to group status by Poulton et al. (1982) following more detailed work which indicated that several subdivisions of regional significance can be recognized. Most of them correspond approximately with the members which Jeletzky (1967) recognized, but the recognition of a major disconformity within one of Jeletzky's sandstone units led to the description of two entirely new units. The youngest major Jurassic basin-margin

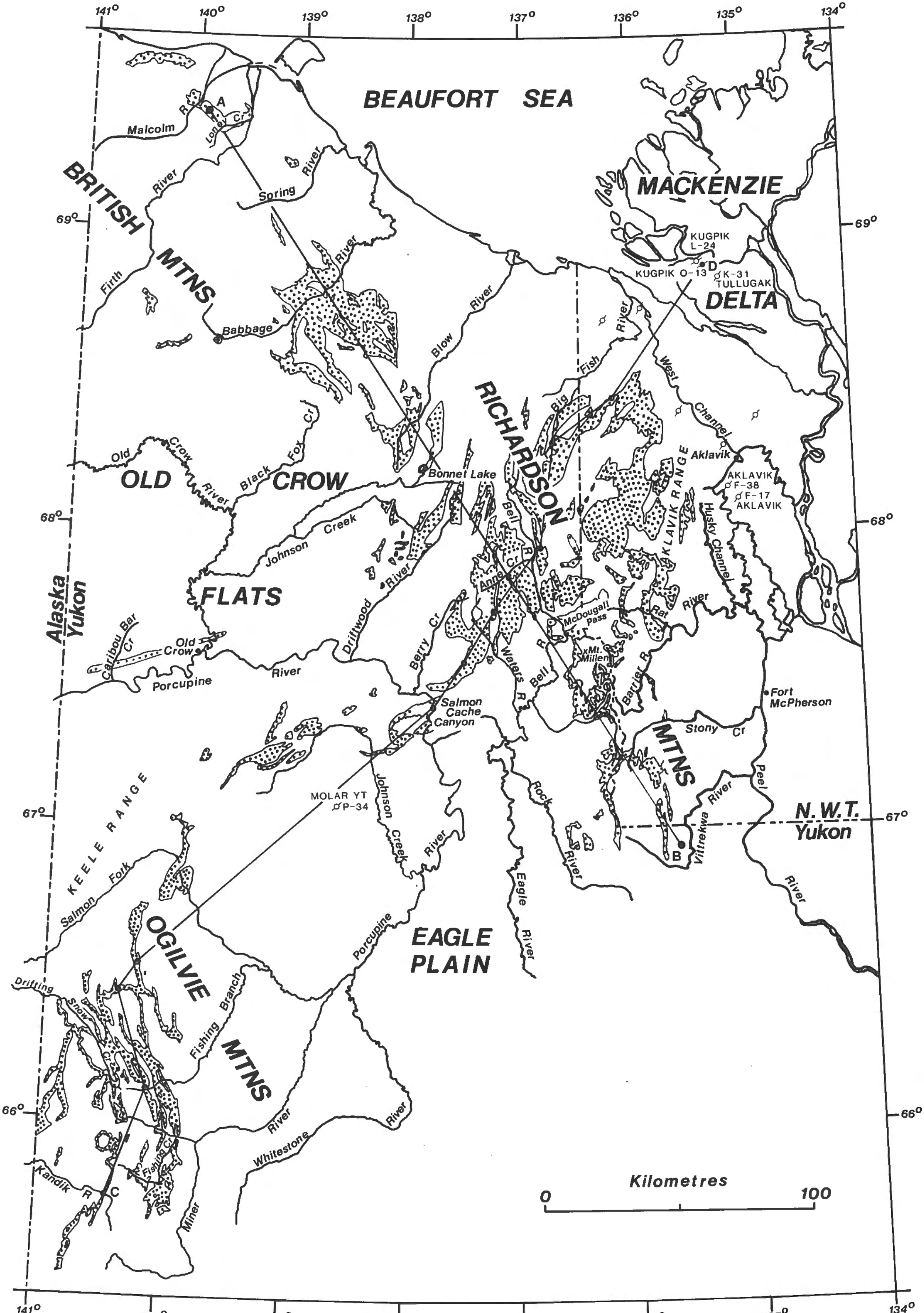


Figure 10.1. *Index map showing the localities cited in the text, and the outcrop of Jurassic rocks (stippled). The locations of cross-section lines A–B and C–D are shown.*

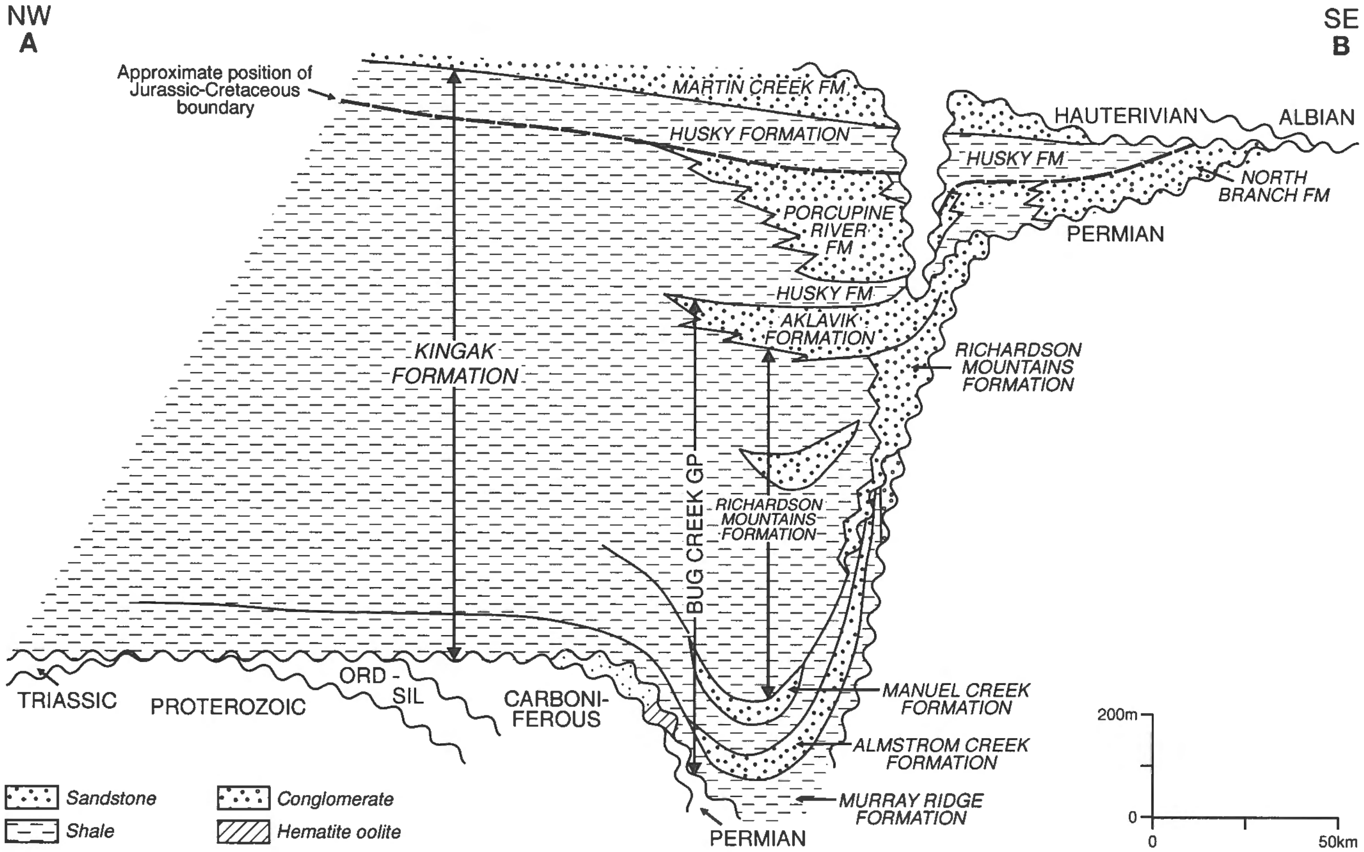


Figure 10.2. *Generalized stratigraphic cross-section A–B across the depositional strike of Jurassic rocks in northern Richardson Mountains. The location of the section is shown in Figure 10.1.*

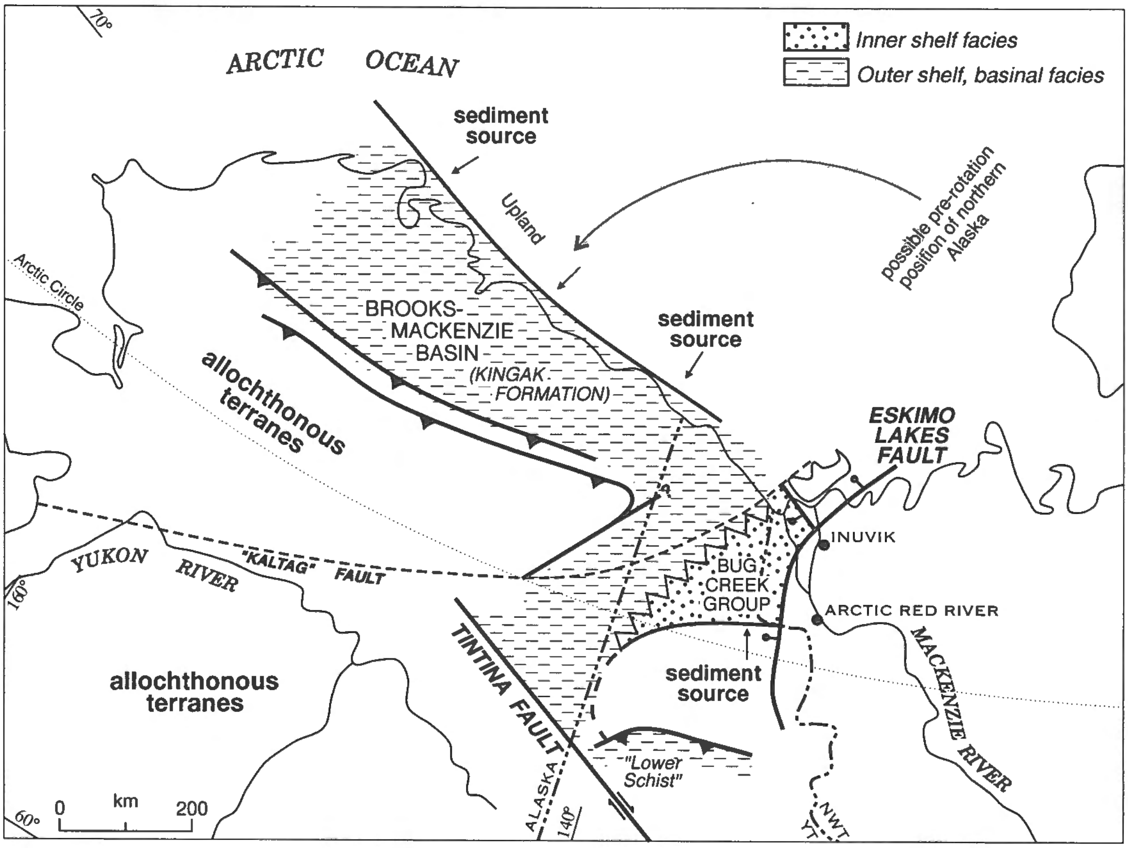


Figure 10.3. *Regional tectonic setting of Jurassic Brooks–Mackenzie Basin of northwestern Canada.*

sequence comprises the Husky shale, and the Porcupine River and North Branch sandstones. The argillaceous basinal or outer shelf succession to the northwest and west (Fig. 10.5) is the Kingak Formation, originally named by Leffingwell (1919) in northeastern Alaska. The name has been applied in northern Yukon because of lithological and paleontological similarities with the Alaska unit, and because the physical continuity of the Jurassic shale units is interrupted for only a short distance along the Arctic coast at the Yukon/Alaska border.

Southeastward, toward the craton, sandstone becomes increasingly dominant in the Jurassic strata

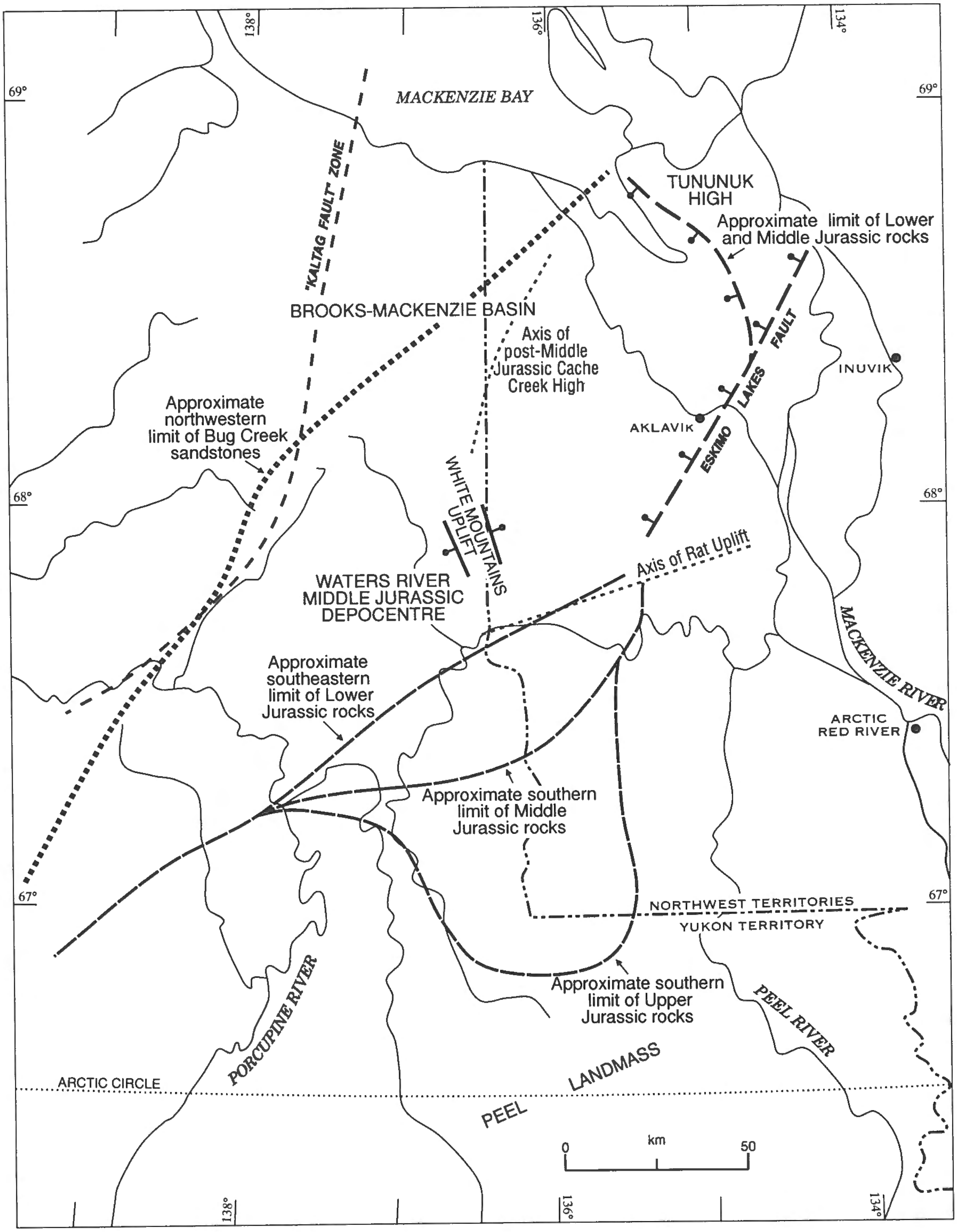


Figure 10.4. Paleogeographic-tectonic elements of northern Yukon and adjacent Northwest Territories which affected Lower and Middle Jurassic depositional patterns.

and hiatuses become more pronounced. Each successive major sequence overlaps the one below, and the Jurassic package as a whole becomes thinner, eventually to become absent where the Cretaceous directly overlies Paleozoic rocks. The record is of intermittent, increasingly extensive, transgression of the northwestern margin of the North American craton.

The basin margin or inner shelf facies, including argillaceous formations that are tongues of the Kingak, are exposed principally in the northern Richardson Mountains. They are relatively well exposed there because of the resistance to weathering of the sandstone units, and are fossiliferous at several horizons. These strata also have been penetrated by wells drilled in the western parts of the Mackenzie Delta (Poulton, 1978a; Dixon, 1982a), and have been recognized (Poulton et al., 1982; Poulton, 1982) west and southwest of the northern Richardson Mountains along northeastern Keele Range.

The Jurassic sediments are thought to have been derived from the craton exposed to the southeast although they are all in marine shelf facies in which diagnostic criteria for paleocurrents and provenance are lacking. Most of the arenaceous components can be attributed to the reworking of Paleozoic sedimentary rocks like those exposed in the northern Richardson Mountains. The sandstones are quartz-rich and contain abundant locally-derived chert and siltstone fragments wherever Paleozoic rocks underlie them directly or nearby. The small feldspar content of some Lower and Middle Jurassic formations suggests some component of long-distance transport, presumably from the Mackenzie Mountains area of southeastern Yukon or from the Canadian Shield (Poulton et al., 1982). However, southeasterly derivation of the clastic sediments in western localities was disputed by Jeletzky (1975, 1977, 1980) who inferred them to be marginal deposits of a western landmass from which he thought them to have been derived, an early stage of the Brooks Geanticline. He considered this western clastic belt to have been separated from the peri-cratonic succession of eastern and central Richardson Mountains by a marine trough characterized at these latitudes by a condensed neritic to (?)bathyal argillaceous succession. He considered this trough to have extended south-southwestward, through Eagle Plain to Kandik Basin near the head of Kandik River. Arguments against such a paleogeographic pattern and against a western provenance for these rocks were

Table 10.1

Table of formations

SYSTEM	SERIES	STAGE	NORTHERN OGILVIE MOUNTAINS	NORTH-WESTERN YUKON	SALMON CACHE CANYON		BONNET LAKE AREA
JURASSIC	UPPER	TITHONIAN	*PORCUPINE RIVER FM* ss			*PORCUPINE RIVER FORMATION* ss	*PORCUPINE RIVER FM* ss
		KIMMERIDGIAN					
		OXFORDIAN	*KINGAK FORMATION*	*KINGAK FORMATION*		*HUSKY FORMATION* sh	*KINGAK FORMATION*
					BUG CREEK GROUP	*AKLAVIK FORMATION* ss	
	MIDDLE	CALLOVIAN				*RICHARDSON MOUNTAINS FORMATION* sltst ss *Waters River Member* ss	
		BATHONIAN					
		BAJOCIAN				*LIttle Bell Member* ss	
		AALENIAN				*MANUEL CREEK FORMATION* sh sltst ss	ss
	LOWER	TOARCIAN					
		PLIENSBACHIAN				*ALMSTROM CREEK FORMATION* ss	
		SINEMURIAN		sh sltst		*MURRAY RIDGE FORMATION* sh sltst ss ls	sh sltst
		HETTANGIAN	sh sltst	?		?	?

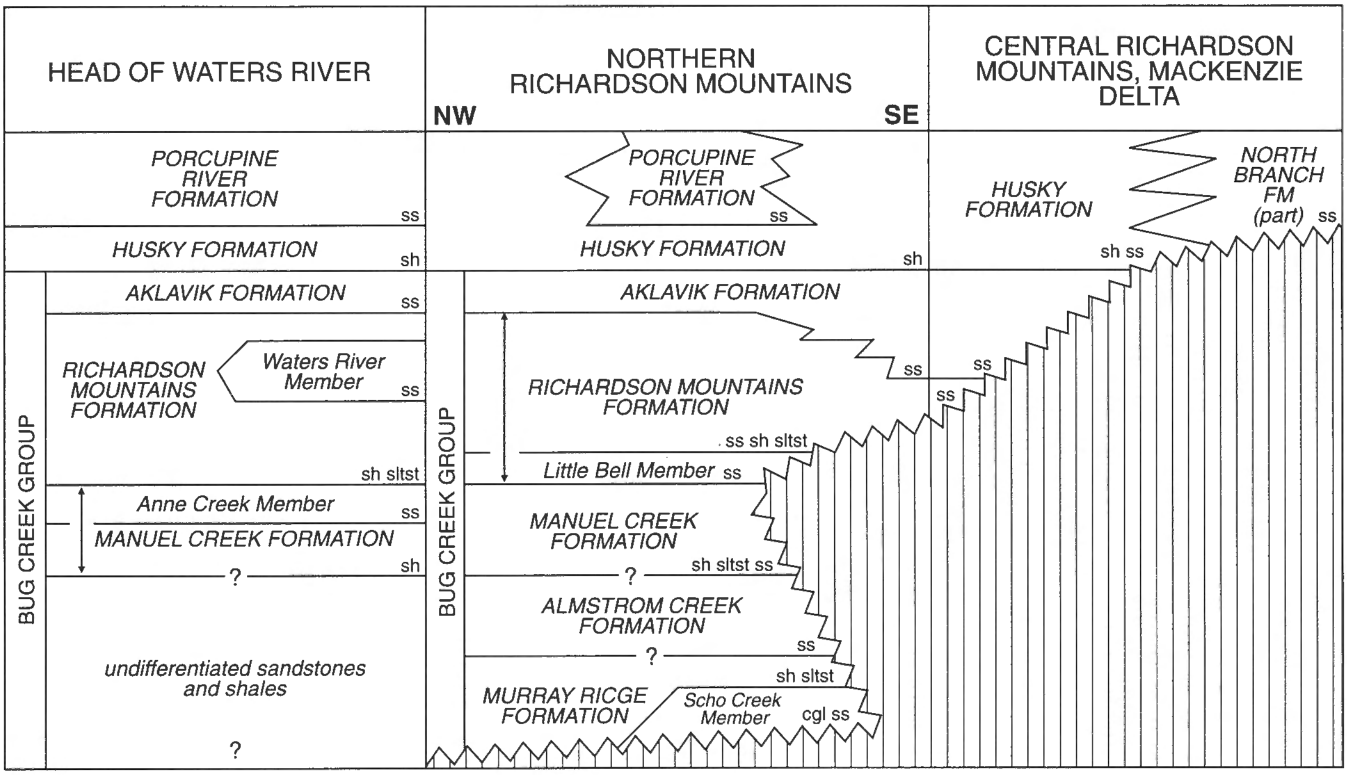
given by Poulton (1982) and are not repeated here. Rather, a modified version of the paleogeographic scheme of Moorhouse (1966) and Young et al. (1976, fig. 4) seems to fit the available data better. There is no conclusive evidence for the existence of Brooks Geanticline before Late Jurassic time and there is no indication that it had any influence in Canada during the Jurassic. The whole area north of Ogilvie Mountains was probably occupied by a shallow marine shelf that, together with the similar, but perhaps tectonically dislocated, shelf that underlies northern Alaska, formed the northwestern corner of the North American continent during the Jurassic.

The Kingak shales and siltstones (''outer shelf facies'' on Fig. 10.5; Table 10.1), west and northwest of the Richardson Mountains and north of approximately latitude 67°30′N, weather recessively and mainly occupy low areas where they are not exposed, or occur as fine rubble transported down gentle slopes by solifluction, or as outcrops in the banks of creeks. Individual outcrops commonly cannot be confidently related to each other to provide a reliable stratigraphic section. Fossils occur sporadically, which indicates that faulting and folding have disturbed the unit between, or within, individual outcrops.

Northern Yukon is cut by a complex fault zone which was postulated (Norris, 1974) to be an extension of the Kaltag Fault from western Alaska into northern Yukon and the Blow River fault zone (see Figs. 10.3, 10.4). Some jostling of slices within this fault zone at several different times is indicated by unusual stratigraphic relationships at several localities (Norris, 1976). Large scale horizontal displacement along this fault in the Yukon has not been unequivocally confirmed by workers in Paleozoic rocks; the Jurassic rocks do not permit any conclusive statement regarding displacement on the fault (Poulton, 1982). Assumption of relatively little differential movement along this fault zone does not preclude the possibility of Jurassic or younger strike slip movement of one part of the basin against the other on a scale smaller than that of the basin (i.e., in the order of 200 km or less).

The name Kingak Formation is also applied to the predominantly shale-siltstone unit in northern Ogilvie Mountains, although it is geographically close to, and essentially the same as, the Glenn Shale which was named by Brabb (1969) in adjacent Alaska. The argillaceous rocks in the northern Ogilvie Mountains were presumably deposited in physical continuity with the Kingak Formation on the north slope of Yukon. It

Table 10.1 cont'd



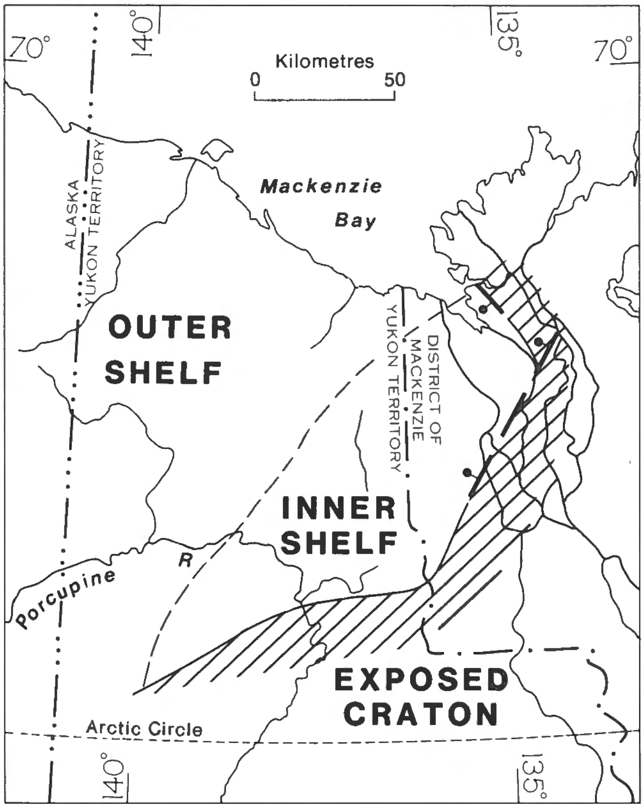


Figure 10.5. Major facies belts of the Jurassic of northern Yukon and adjacent Northwest Territories.

is lithologically similar to the Kingak Formation, especially to its upper parts which are of Late Jurassic age. They are, however, separated from the Kingak rocks to the north by a fault zone, which has been interpreted as the possible extension of the Kaltag Fault from Alaska, which may be the locus of some transcurrent motion (Norris, 1974; Chapter 3). Furthermore, if northern Alaska rotated counterclockwise away from the Canadian Arctic Islands, with or without associated transcurrent motion, then the Jurassic shale of northwesternmost Yukon came with it.

Jurassic transgression northward or eastward onto a 'high' in northwesternmost Yukon was suggested by Norris (1972, 1973, 1974) who recognized the probable Kingak shales overstepping Triassic strata northward or eastward onto older (Lower Paleozoic according to Lane and Cecile, 1989) rocks in the Spring River area. Unlike in the equivalent rocks in northern Alaska, there are no coarse lithologies in the Kingak Formation of the Spring River locality that conclusively indicate a northern source. Turbidites in the late Pliensbachian part of the thick fossiliferous Kingak succession at Loney Creek near the mouth of Firth River may be derived from a northern source but it has not yet been possible to measure paleocurrent directions in them. They could equally well be distal equivalents of the Pliensbachian shallow marine sandstones to the southeast.

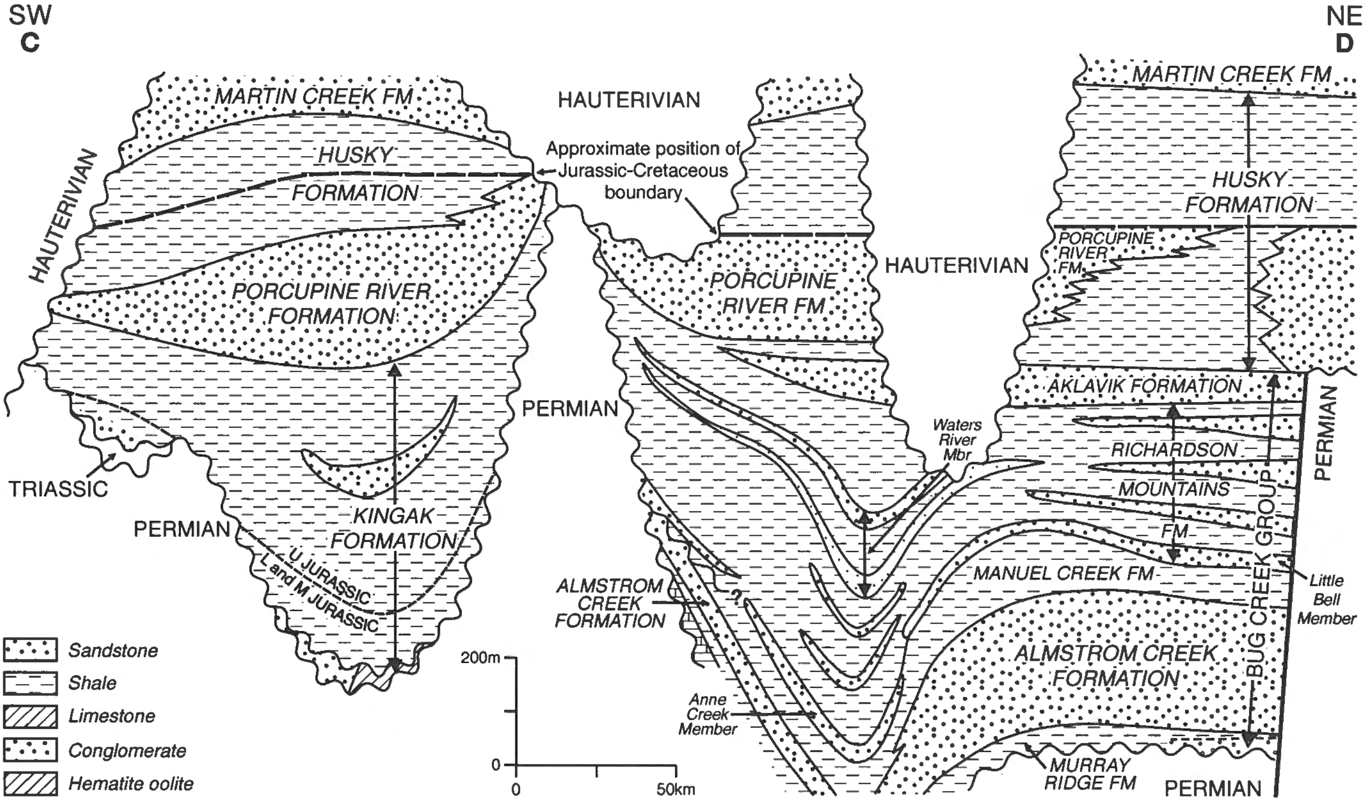


Figure 10.6. Stratigraphic cross-section C–D along depositional strike. The location of the section is shown in Figure 10.1.

The basin margin Bug Creek succession in the subsurface of the Mackenzie Delta terminates abruptly to the northeast against Tununuk High along a northwest-trending locus near Reindeer Channel (e.g., Dixon, 1982a; Figs. 10.4, 10.6). This high was transgressed by the Husky Formation. Although unlikely, it seems this termination may reflect a Bug Creek depositional margin rather than post-Bug Creek erosion over a fault block. This would indicate a northwestward swing of the otherwise northeastward-trending thickness and facies trends (Fig. 10.3). In turn, this might support a connection, in the Jurassic, between the North American cratonic margin and the Arctic Platform lying north of Alaska, rather than the Arctic Platform of the Canadian Arctic Islands which is more generally supposed (e.g., Balkwill et al., 1983).

SOUTHEASTERN BASIN-MARGINAL ARENACEOUS BELT

The Jurassic sandstone wedges of the northern Richardson Mountains and northwestern Mackenzie Delta extend west as far as the head of Johnson Creek near Bonnet Lake and in discontinuous outcrop within a 30 to 40 km wide belt extending from between Driftwood and Bell rivers southwestward to northern Ogilvie Mountains. Jurassic rocks are not now thought to be present in the subsurface of Eagle Plain (Young et al., 1976; Poulton, 1982) although Jeletzky (1975, 1980) postulated them to have been there. All these Jurassic rocks are probably shelf marginal deposits of the craton to the southeast, or basinward extensions of them rather than being marginal to and derived from any western landmass as Jeletzky (1975) thought. Their essential continuity with the type Bug Creek Group was shown by Poulton et al. (1982). The more western of these occurrences are nevertheless different from the Bug Creek Group in its more typical exposures in northern Richardson Mountains, in terms of the stratigraphic position and relative importance of some of the sandstone units.

Northern Richardson Mountains—central and eastern parts

The Bug Creek Group is exposed in its typical facies development in the Richardson Mountains north of Mount Millen (approximately lat. 67°30′N) and east of Bell River (approximately long. 137°W). It comprises a succession of sandstone and shale-siltstone formations which becomes thicker (Fig. 10.7), more complete, and more predominantly argillaceous to the north and west within this area (Poulton et al., 1982). In the Aklavik Range, where the Bug Creek Group was initially described as a formation by Jeletzky (1967), it is unusually thin, nearly entirely arenaceous, and incomplete. The sandstone formations have characteristics indicating shallow-water shelf deposition, but the two shale formations, the Murray Ridge and Manuel Creek formations, were probably deposited below storm wave-base. Thin basal conglomerates occur locally along the eastern basin margin where their occurrence was apparently controlled by relief on a contemporaneous fault (Eskimo Lakes Fault of Young et al., 1976; Fig. 10.4). The Bug Creek Group is overlain by the Husky Formation shale and a thin tongue of the Porcupine River sandstone, both Upper Jurassic, in the northern Richardson Mountains.

The lowest formation of the Bug Creek Group, the Murray Ridge Formation, consists of shale and siltstone, becoming coarser upward and grading into overlying sandstones of the Almstrom Creek Formation. It reaches 75 m in thickness in northwestern localities. There is commonly a basal phosphatic and ferruginous, fossiliferous chert-pebble bed less than 1 m thick. In the easternmost localities, such as at Scho Creek, Bug Creek, and Jurassic Butte, a basal sandstone and pebble conglomerate, the Scho Creek Member, occurs, reaching 24 m in thickness (Fig. 10.8). The Murray Ridge Formation contains Upper Sinemurian ammonites—*Echioceras*, *Oxynoticeras* and *Aegasteroceras* (*Arctoasteroceras*)—in the eastern parts of the northern Richardson Mountains. In the western parts of the northern Richardson Mountains, as near Big Fish River, Lower Sinemurian *Coroniceras* occurs (Poulton, 1991). Articulated crinoids on some bedding surfaces suggest deposition below wave base (Poulton et al., 1982).

The Murray Ridge Formation is overlain by the Almstrom Creek Formation (Figs. 10.9, 10.10), a sandstone unit reaching 300 m in thickness in its northwestern occurrences near the head of Big Fish River. It is characterized by *Lingula*(?) in some beds, a variety of bivalves including oysters, *Liotrigonia*, and large *Pholadomya*, and contains rare *Amaltheus*, an ammonite of Late Pliensbachian age. Hummocky cross-stratification, glauconite, and red weathering concretionary layers are characteristic as well.

Shales, grading up into sandstones (Anne Creek Member), comprise the overlying Manuel Creek Formation, which contains the Toarcian ammonites *Dactylioceras* and *Pseudolioceras* in its lower parts and Aalenian *Pseudolioceras* and *Erycitoides* in its upper parts. The formation exceeds 100 m in thickness in northwestern occurrences.

Bajocian and younger strata of the Richardson Mountains Formation overlie these Lower Jurassic and Aalenian strata disconformably, and overlap them in the southeast. The Little Bell Member, the basal sandstone at many localities, contains a thin basal phosphatic and fossiliferous unit in which the Lower Bajocian ammonite *Arkelloceras* occurs. Higher beds in the Little Bell Member, and eastern facies of it, are characterized by Upper Bajocian *Cranocephalites*. The higher, major parts of the Richardson Mountains Formation comprise interbedded sandstones, shales and siltstones (Figs. 10.11-10.13), thickening and becoming finer grained toward the west, where the formation reaches a maximum thickness in excess of

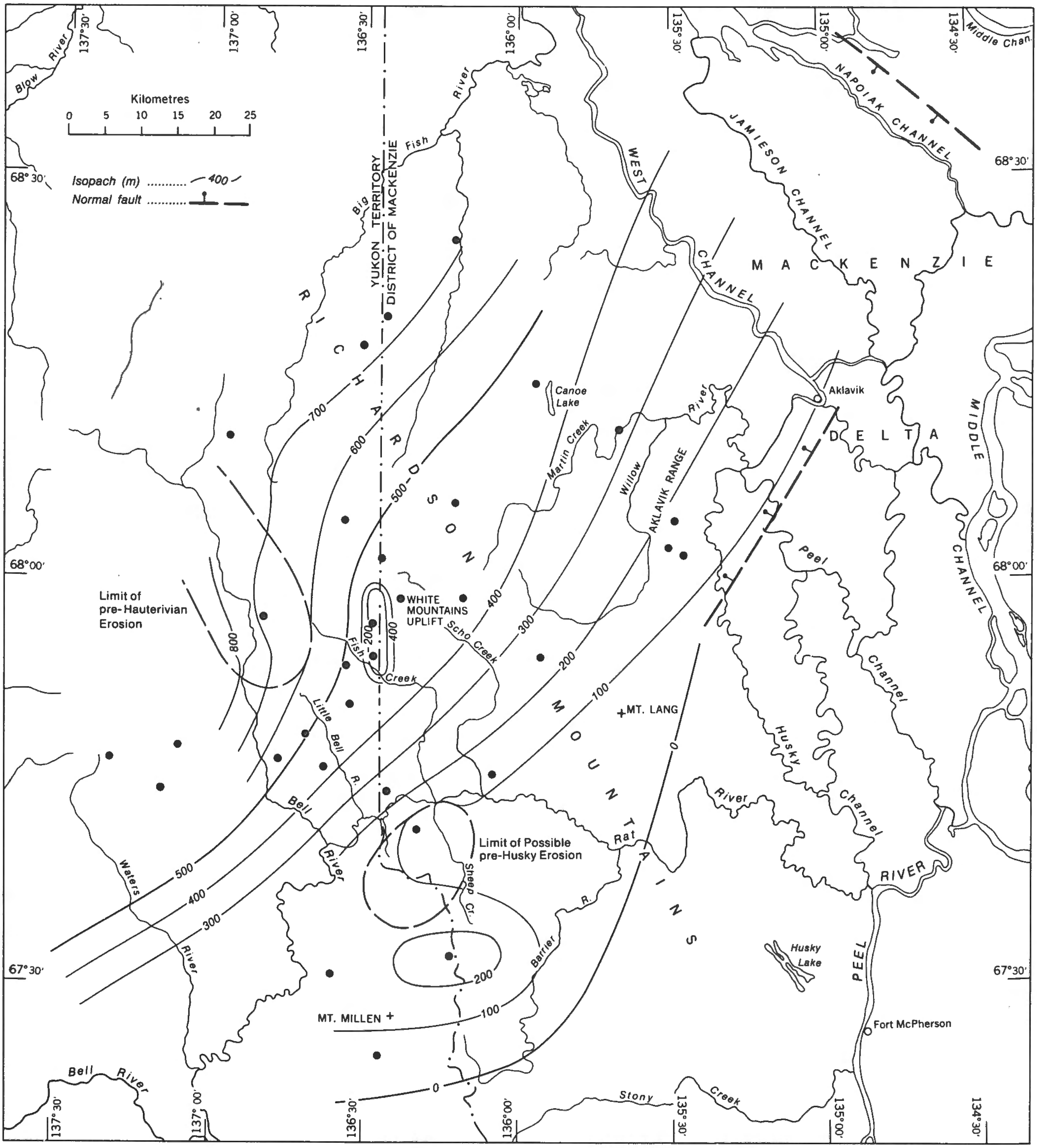


Figure 10.7. Isopach map of pre-Late Oxfordian Jurassic rocks (Bug Creek Group) in northern Richardson Mountains and adjacent Mackenzie Delta. The dots indicate locations of measured sections.

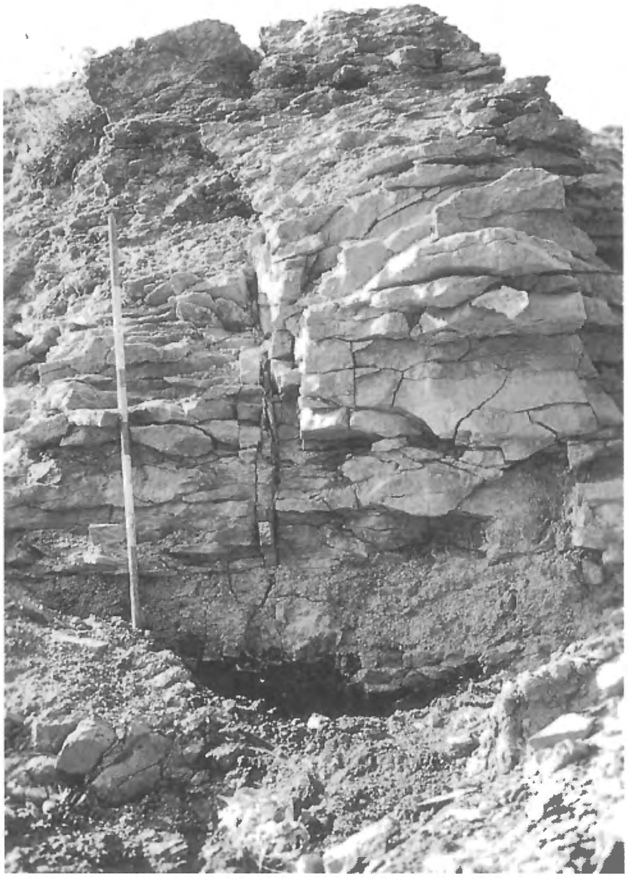


Figure 10.8. Basal Jurassic Scho Creek sandstone of Murray Ridge Formation, Bug Creek Group (lat. 68°04'30"N, long. 135°28'20"W; Section PU-7-75 of Poulton et al., 1982). GSC photo 202910-D.

600 m and grades basinward into the Kingak Formation. The Richardson Mountains Formation contains Bathonian *Arctocephalites*, *Arcticoceras*, Bathonian to Callovian *Cadoceras* at many localities, and Lower Oxfordian *Cardioceras* at its top.

The Richardson Mountains Formation grades upward into the Aklavik Formation, a sandstone unit that forms spectacular bluffs in the vicinity of Bug Creek, Martin Creek, and farther south to beyond McDougall Pass. It is a shelf sandstone noted for abundant and well developed crossbedding, and less pervasive bioturbation. At many localities, particularly in western occurrences, two or three sandstone units are present. Some of these sequences resemble offshore barrier sequences (Poulton et al., 1982), although no unequivocal back-barrier lagoonal facies have been identified (Fig. 10.14). In the eastern part of the northern Richardson Mountains, an upper sandstone of the Richardson Mountains Formation appears to be an offshore sandstone facies lying below a recessive, argillaceous, strongly bioturbated unit that underlies the crossbedded sandstone of the Aklavik Formation (Fig. 10.15).

The Aklavik Formation is overlain abruptly by marine shales of the Husky Formation, which overlaps the Bug Creek Group to the east, northeast and southeast. The Husky Formation (Fig. 10.16) contains a sequence of species of the bivalve *Buchia*, which indicate Late Oxfordian through earliest Cretaceous ages. In the eastern part of the northern Richardson Mountains, a thin sandstone unit containing *Buchia concentrica* (Sowerby) represents a thin northeastern tongue of the Porcupine River Formation.

Shelf sandstones of very shallow-water marine origin south of Barrier River, and included in the North Branch Formation (Jeletzky, 1967; Fig. 10.17), are the most cratonward facies preserved. The sandstones pass northward into the arenaceous member of the Husky Formation in the Mackenzie Delta area and northernmost Richardson Mountains (Jeletzky, 1967, 1975; Dixon, 1982a, b; Braman, 1985).

A small uplift on the unstable inner shelf, White Mountains Uplift (Figs. 10.4, 10.7; Poulton and Callomon, 1976), lay just basinward of the Bug Creek Group's southeastern limits. It was possibly a precursor to the more extensive Cache Creek Uplift of Cretaceous time (Norris, 1973; Young et al., 1976; Jeletzky, 1980). Earlier Jurassic rocks were eroded over White Mountains Uplift prior to Late Bajocian deposition (Poulton et al., 1982). The uplift could represent one small fault block within a rifting or transcurrent fault regime, which was uplifted by jostling in Jurassic time, and possibly localized by the anomalous Paleozoic buildup of carbonate rocks which occurs in this small area.

Regional thickness and facies trends within some of the Lower Jurassic units (Fig. 10.18) indicate that the southeasterly thinning onto the craton is partly due to original depositional thickness variation and partly to pre-Bajocian erosion associated with a Canada-wide Aalenian to Early Bajocian regressive event (Poulton, 1988b).

Bajocian and younger Bug Creek Group strata are relatively thin over White Mountains Uplift and in a salient extending northwestward from it (Fig. 10.19), which coincides geographically with the depocentre of the older Almstrom Creek sandstone. The salient may be a result of relatively less differential compaction there than in the adjacent more argillaceous rocks.

Figure 10.9. *Permian* (P) *and Jurassic rocks between Canoe Lake and Almstrom Creek. The resistant Permian limestone unit (light band, upper one third of photo) is overlain successively by recessive Sinemurian Murray Ridge shales* (Jmr) *and resistant Pliensbachian Almstrom Creek sandstones* (Jac) *(approximately lat. 68°08′N, long. 136°09′W). ISPG photo 974–19.*

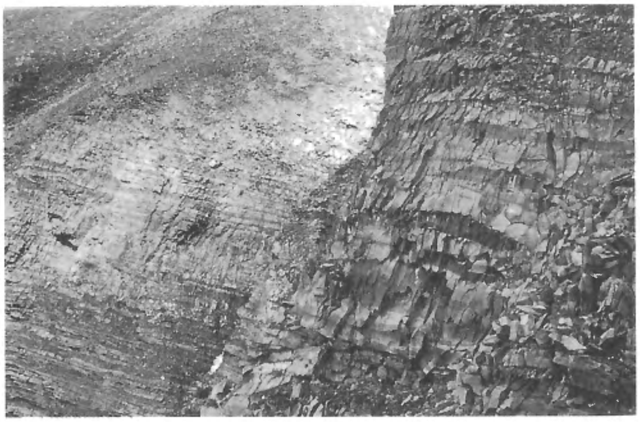


Figure 10.10. *Pliensbachian Almstrom Creek sandstone showing hummocky crossbedding emphasized by dark, red (ferruginous) and light, green (glauconitic, not ferruginous) banding, Murray Ridge (about lat. 67°58′30″N, long. 136°22′30″W; near Section 116 P6 of Norris, 1980a). ISPG photo 1217–5.*

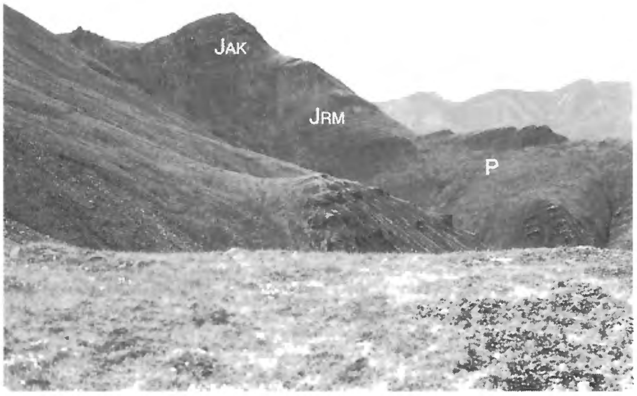


Figure 10.11. *Middle Jurassic through Oxfordian Richardson Mountains* (JRM) *and Aklavik sandstones (*JAK*; top, resistant) overlying well-bedded Permian sandstones (*P*; middle ground). A southwestward-directed spur of the ridge immediately east of White Mountains and of the headwaters of Fish Creek (about lat. 67°54′30″N, long. 136°28′40″W; Section PU-1-75 of Poulton et al., 1982). ISPG photo 2564–14.*

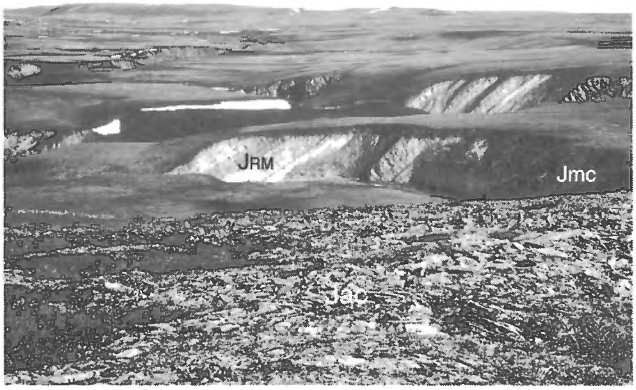


Figure 10.12. *Bug Creek Group exposed in banks near the junction of Almstrom and Little Fish creeks (about lat. 68°25′N, long. 136°11′W; Section PU-20-76 of Poulton et al., 1982); Pliensbachian Almstrom Creek sandstone slabs in the foreground* (Jac)*; Toarcian Manuel Creek shale in the recessive interval* (Jmc*; centre, right); and Middle Jurassic offshore-bar sandstones within Richardson Mountains Formation (*JRM*; centre). ISPG photo 974–15.*

East and northeast of this salient, the northwestward thickening of the Richardson Mountains Formation is very gradual. West and west-southwest of White Mountains and the salient of relatively thin Bajocian and younger rocks, however, basinward thickening of the Richardson Mountains Formation is very rapid. The combined effects of the White Mountains Uplift and its northwestward extension in the Middle Jurassic, together with pre-Hauterivian erosion west of it, are expressed by the Bug Creek Group as a whole, exhibiting abrupt thickening southwest of White Mountains (Poulton et al., 1982).

The Bajocian and younger upper package of the Bug Creek Group extends southward beyond the limits of the lower package, from McDougall Pass to Mount Millen (compare Figs. 10.18 and 10.19). The southernmost exposure that is physically continuous with the Bug Creek Group in the Richardson Mountains Formation lies about 8 km south of Mount Millen. Here it is unusual, however, occurring largely in coarse conglomeratic facies. Farther north, in the Aklavik Formation, grit of similar composition

***Figure 10.13. Inoceramus** and belemnites littering a sandstone surface, Middle Jurassic Richardson Mountains Formation south of the White Mountains and 3 km southwest of the confluence of Vunta and Fish creeks (lat. 67°54′N, long. 136°35′W; Section PU-4-78 of Poulton et al., 1982 and at or near Section 116 P5 of Norris, 1980a). ISPG photo 1202-3.*

***Figure 10.14.** Upper Jurassic sequence on a ridge between Big Fish River and Little Fish Creek (about lat. 68°18′N, long. 136°31′W; Section PU-19-76 of Poulton et al., 1982 and at or near Section 117 A5 of Norris, 1980b). Recessive argillaceous rocks of the Richardson Mountains Formation (JRM; foreground) are overlain successively by three coarsening-upward sandstone cycles of the Oxfordian Aklavik Formation (JAK), recessive shales of the lower Husky tongue (JKH), and latest Jurassic Porcupine River sandstones (JPO; skyline). ISPG photo 2564-19 by Dwayne Hope.*

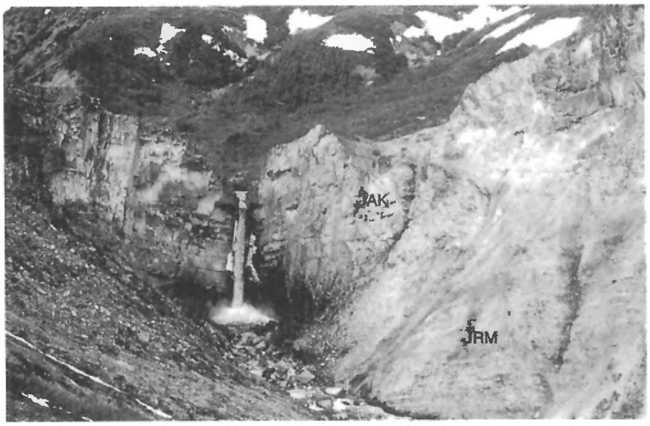


***Figure 10.15.** Oxfordian Aklavik sandstone (JAK), the upper part of underlying Richardson Mountains Formation (JRM), and the lower part of Husky Formation (JKH) (approximately lat. 68°07′N, long. 135°51′W). ISPG photo 3625-2.*

suggests correlation between these areas (Poulton et al., 1982). Conglomerate and sandstone occurrences farther south, at the heads of Stony Creek and the north branch of Vittrekwa River, which Jeletzky (1975) and Young et al. (1976) thought to be nonmarine facies of the Bug Creek Group, have been subsequently mapped instead as the younger North Branch Formation (Norris, 1980a) which can be considered a local facies variant of younger parts of the Porcupine River Formation. Thus, no southern or eastern nonmarine Jurassic facies are known in northern Yukon or northwestern Northwest Territories, and the entire Jurassic sequence is a marine package in which interpretations of provenance cannot be firmly documented by variation to nonmarine facies.

Figure 10.16. *Upper Jurassic shales with a sandstone rib ('arenaceous member') of the Husky Formation at Treeless Creek, northern Richardson Mountains (lat. 67°52′N, long. 135°37′W). ISPG photo 3625–1 by J. Dixon.*

Figure 10.17. *Uppermost Jurassic North Branch Formation sandstones near the type section on the north branch of Vittrekwa River (lat. 67°05′N, long. 135°43′W; Norris, 1980c, Section 106 M1). The upper coarsening-upward cycle of the original formation (Jeletzky, 1967) is now known to be Barremian in age. It is mapped as part of the Mount Goodenough Formation. ISPG photo 2564–17.*

Upper Oxfordian and overlying Jurassic rocks exhibit a depositional geometry, basically similar to that of the underlying Bug Creek Group, but are transgressive over a broader area onto the craton. Their facies indicate easterly or east-southeasterly sediment sources near the head of Vittrekwa River. The sandstones extend basinward in shallow marine facies, grading into the Husky shale to the north and the Kingak shale to the west and south.

Mackenzie Delta

The Bug Creek Group occurs in the subsurface of Mackenzie Delta in wells from Aklavik F-38 in the south, to at least as far north as Unak B-11. The units present, their thicknesses, and lithologies, all appear to indicate a simple northeastward extension along depositional strike of the equivalent succession in the adjacent Richardson Mountains, but they may not extend as far as previously reported (Poulton, 1978a; Dixon, 1982a).

The southeastern limit of most, if not all, formations of the Bug Creek Group in the delta occurs between wells Aklavik F-38 and F-17 (Fig. 10.1), along the locus of a major strand of the Eskimo Lakes Fault zone (Fig. 10.4). Dixon (1982a) suggested that a thin sandstone at the base of the Husky Formation in Aklavik F-17 also represents the Bug Creek Group. Thinning trends of several formations of the Bug Creek Group indicate that their depositional margins in Jurassic time lay near this locus, although some of them may have extended a short distance farther southeast and been eroded prior to deposition of the Cretaceous rocks.

Lower and Middle Jurassic rocks apparently do not pass northeastward into a siltstone facies in the northeastern part of the delta as previously thought (Young et al., 1976); rather, they appear to be absent there, and the younger Husky Formation overlies Paleozoic rocks unconformably. Dixon (1982a) showed the Bug Creek Group to be absent in the Kugpik O-13 well, where Poulton (1978a) indicated a thin section to be present, but he (Dixon, pers. comm., 1991) now believes it to be absent north of Unak B-11.

The abrupt contrast between the normal Bug Creek section in Unak B-11 and its absence farther north, approaching the Cretaceous Tununuk High (Dixon, 1982a), suggests that the high may be bounded on its southwest side by a fault that was active prior to the Late Jurassic (Fig. 10.4). Pre-Husky erosion may be responsible for removal of the Bug Creek rocks on the Tununuk High because no gradual thinning of Bug Creek strata toward the northeast is indicated. Alternatively, the abrupt northeastward disappearance

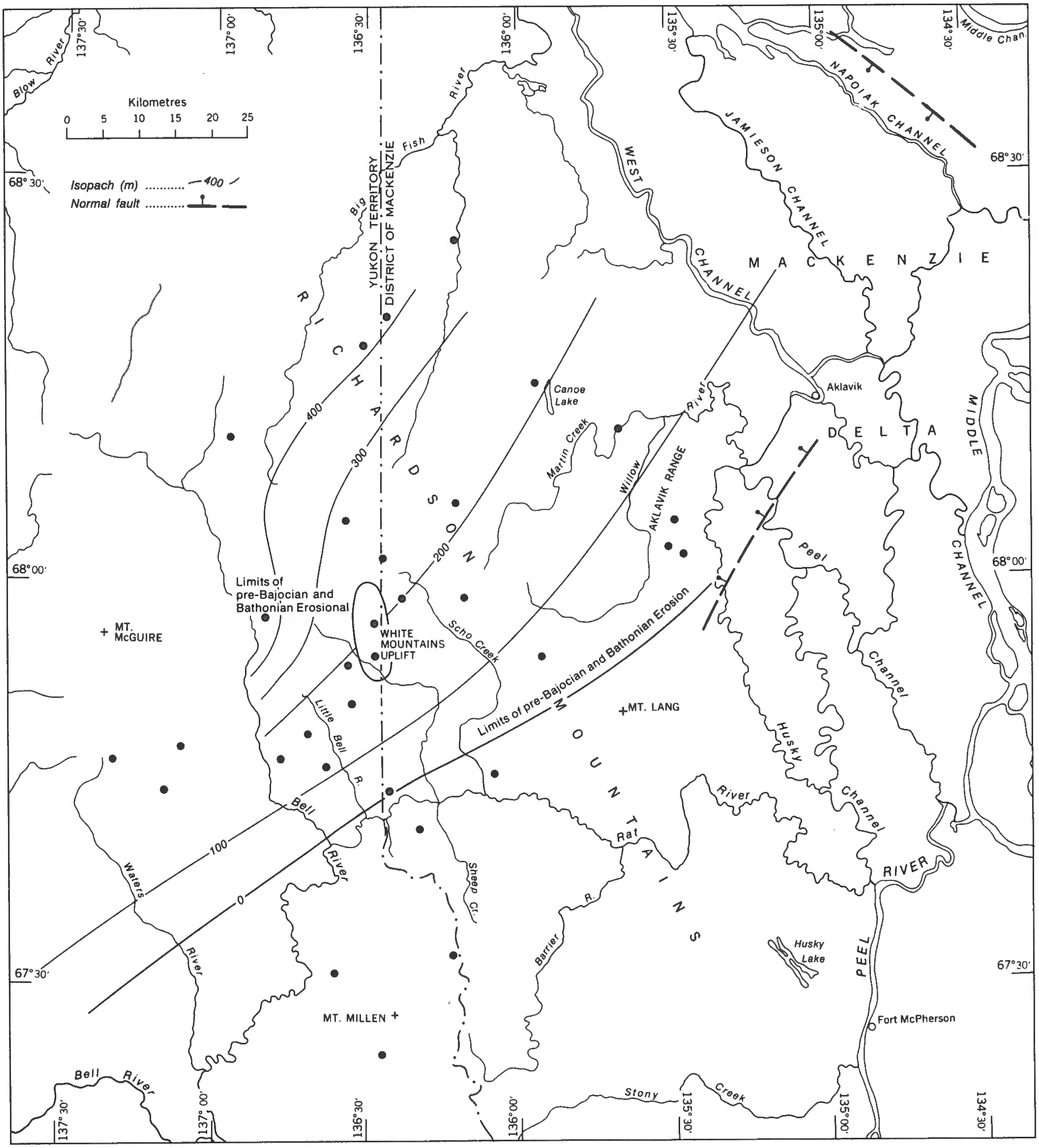


Figure 10.18. Isopach map of the lower formations of the Bug Creek Group (Murray Ridge to Manuel Creek formations) in the northern Richardsons and adjacent Mackenzie Delta.

of the Bug Creek might be depositional. However, if a Jurassic shoreline was present in that vicinity, it is not indicated by facies trends in the Bug Creek Group and it would have had a northwestward trend, anomalous when compared to that elsewhere along the basin margin (Fig. 10.3). Rather than a relatively simple extension of the Jurassic shorelines northeastward from Richardson Mountains around Banks Island to Prince Patrick Island (e.g., Balkwill et al., 1983), these stratigraphic relationships suggest either a major irregularity in that shoreline, or a totally different configuration involving a connection of the cratonic

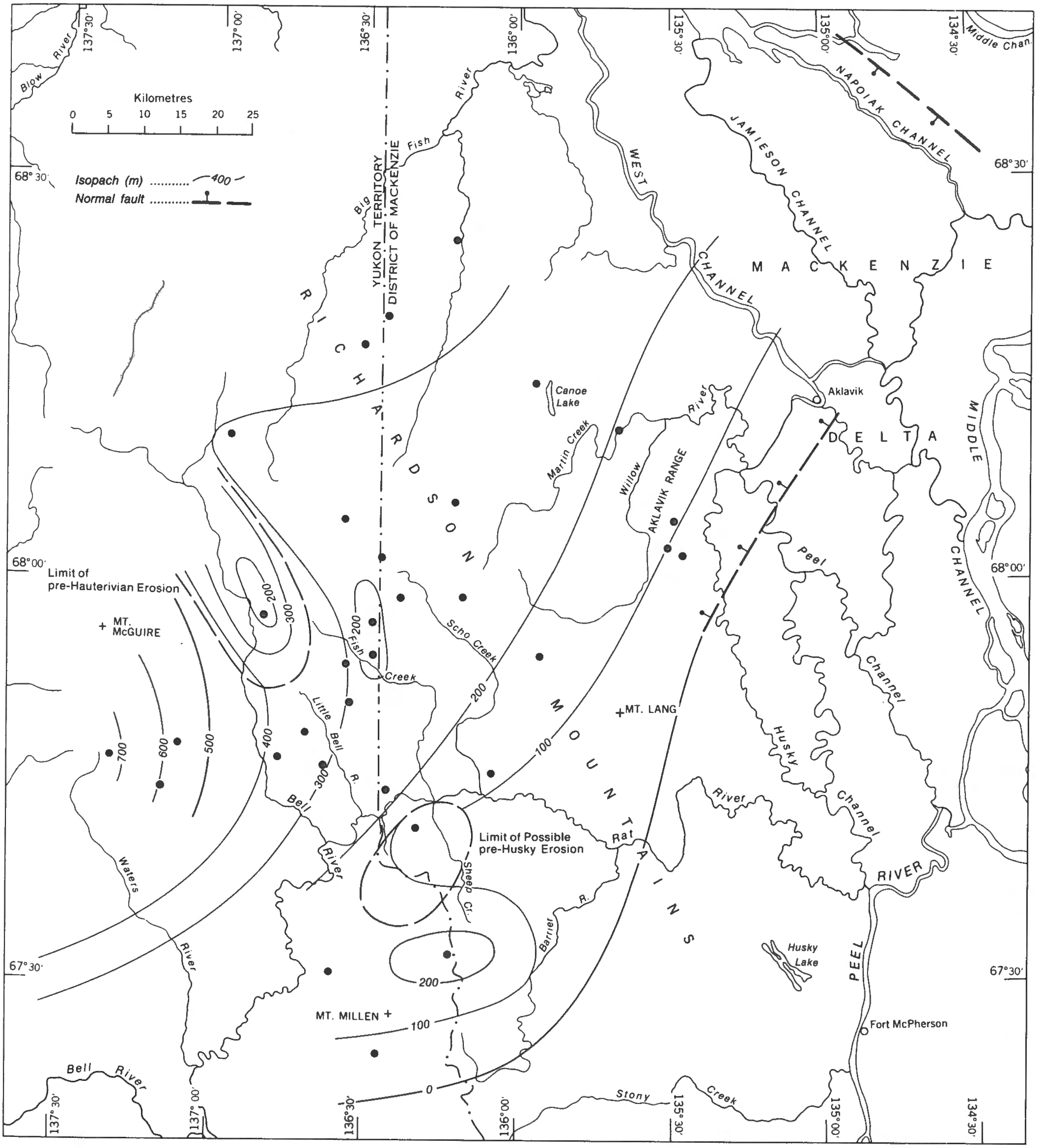


Figure 10.19. Isopach map of the upper subdivisions of the Bug Creek Group (Richardson Mountains and Aklavik formations) in the northern Richardson Mountains and adjacent Mackenzie Delta.

margin of Mackenzie Delta area with the Arctic Platform lying off northern Alaska (Barrow Arch) in Jurassic time.

The Upper Jurassic and lowest Cretaceous Husky shale sequence is transgressive eastward in the Mackenzie Delta area, beyond the (probably) fault-controlled limits of older Jurassic rocks, resting on Paleozoic and Proterozoic rocks in the Kugpik O-13 and Tullugak K-31 wells in northern Mackenzie Delta, and perhaps in Aklavik F-17 well near Aklavik (Dixon, 1982a, b; Braman, 1985). The sequence was deposited as far east as northern Anderson Plain, where it is included in the mainly Lower Cretaceous Langton Bay Formation by Brideaux and Fisher (1976; Balkwill et al., 1983).

Northern Richardson Mountains—western parts

The succession of sandstones and shales exposed between the upper reaches of Bell River and Berry Creek (Fig. 10.1) is slightly different from that in the central and eastern parts of the northern Richardson Mountains, although it is continuous with that succession and is assigned to the same formations (Poulton et al., 1982; Poulton, 1982). Fossil occurrences in the area permit correlation of the formations there with those farther east in the Richardson Mountains. In the well exposed, northeastern outcrops, such as those near the head of Anne Creek, slightly thicker units of sandstone and shale of Aalenian and older age are overlain by a highly expanded Middle Jurassic shale unit (Richardson Mountains Formation) that contains significant sandstone units, such as the Waters River Member. The base of the Jurassic has not been identified precisely there, nor have fossils been found in the pre-Toarcian rocks which would indicate their correlation with the formations to the east. The Aklavik Formation is thick near the head of Anne Creek, but not in typical facies, and is overlain by the Husky shale and the Porcupine River sandstone. Although two of the sandstone units here, the Lower Bajocian Anne Creek Member (upper Manuel Creek Formation) and the Lower Callovian Waters River Member, are much thicker than their equivalents to the east, equivalent and similar sandstones do occur to the east, unifying one area with the other paleogeographically (Poulton et al., 1982). The Anne Creek and Waters River members are interpreted as offshore bars or barriers (Poulton et al., 1982). Their position at the western shale-out edge of most of the Bug Creek sandstone units may indicate a break in slope on the depositional surface at the outer edge of the inner shelf.

A similar succession of Lower and Middle Jurassic strata appears to be present, but is less well exposed in its lower parts to the southwest, between Waters River and Berry Creek (e.g., Jeletzky, 1971, p. 211; 1972b, p. 37-39; 1975, figs. 7, 8; Poulton, 1982). The Upper Jurassic units reach a maximum thickness of about 400 m in a depocentre near Salmon Cache Canyon on Porcupine River. Most of the thickening is in the Porcupine River marine sandstone (Jeletzky, 1977), the main development of which lay in a northeast-trending broad band extending from the northern Ogilvie Mountains in the southwest to the headwaters of Big Fish River in the northeast. A thin shale unit representing the lower tongue of the Husky Formation separates the sandstone equivalent of the Aklavik Formation from the higher sandstones of the Porcupine River Formation (Fig. 10.20). Here the Aklavik Formation contains *Cardioceras*, and the Husky Formation contains a typical microflora. This thin shale unit was not recognized by Jeletzky (1977), who called the two similar sandstones together the Porcupine River Formation, nor was it known to Poulton et al. (1982) when they erected the Aklavik Formation, with a type section in the northeastern Richardson Mountains. Nevertheless, Jeletzky (1977) suggested that the lower age limits of the Porcupine River Formation required that equivalents of what is

Figure 10.20. *Upper Jurassic sequence on the ridge east of Berry Creek (lat. 67°35′N, long. 137°24′W; near GSC loc. C-42645 of Norris, 1980a). Bluff-forming sandstones of the Aklavik Formation (JAK; lower left), with Oxfordian* ***Cardioceras*** *on the upper surface, are overlain successively by soft black shales of the lower Husky tongue (JKH), containing a thin, light, buff weathering calcareous band (centre, left), and by resistant sandstones of the Porcupine River Formation (JPO) in which Late Oxfordian or Early Kimmeridgian* ***Buchia concentrica*** *occurs. ISPG photo 2564-18.*

now called the Aklavik Formation be present within it, although there was no firm paleontological basis for such a hypothesis. Jeletzky's (1975) interpretation that some of the sandstones in this succession were westerly derived is not well founded. Rather, increased subsidence in the Middle Jurassic and the different location on the marine shelf seem to be sufficient to explain the differences between these rocks and their equivalents to the east. Their more southerly (i.e., more cratonward) disposition is sufficient to explain the greater proportion of sandstone here than near the head of Anne Creek. The depocentre (Waters River depocentre of Fig. 10.4), represented by the thick Middle Jurassic argillaceous package at the head of Anne Creek, more or less coincides in the time of the development of the White Mountains and Rat uplifts portion of the cratonic margin, and may represent a compensatory sediment trap for these uplifts in a complex, faulted unstable regime.

Eastern Keele Range and Salmon Cache Canyon

The Lower and Middle Jurassic rocks are relatively thin and largely arenaceous where they cross the Porcupine River at Salmon Cache Canyon. McConnell (1891, p. 123D) correctly estimated a thickness of some 800 ft. of shale interbedded with ironstone here, from which he collected the first Jurassic fossils from the area. The section here is well exposed and richly fossiliferous (Poulton, 1978b, 1987). A thin and probably incomplete Lower Jurassic section (Fig. 10.21) is overlain by a thicker Middle Jurassic succession (Fig. 10.22) which is more argillaceous and more richly fossiliferous than equivalent strata in the northern Richardson Mountains. A succession of eight ammonite zones has been established in the Bathonian and Lower Callovian in the Salmon Cache Canyon section (Poulton, 1987). The uppermost unit, confidently dated as Middle Jurassic, is probably the Waters River sandstone, which contains Lower Callovian ammonites. The upper contact between this unit and the overlying Porcupine River Formation (Jeletzky, 1977) is complicated by faulting and is poorly exposed along the Porcupine River in the vicinity of Salmon Cache Canyon. However, the presence of the Aklavik Formation is assumed by interpolation between the section just to the northeast (i.e., east of Berry Creek) and the sandstone (?Aklavik Formation) ridges in the northeast extension of Keele Range in southern Old Crow Flats. The recessive character of most of the Jurassic rocks below this sandstone results in poor exposure of these rocks along strike southwest of Salmon Cache Canyon.

Several occurrences of Jurassic fossils serve to identify Bug Creek Group equivalents in the low ridges of sandstone in the northeastern parts of Keele Range. One (GSC loc. C-27118) contains Callovian *Cadoceras*

Figure 10.21. *Lower Jurassic sequence north of Salmon Cache Canyon, Porcupine River. Recessive shales and resistant sandstones, probably Sinemurian (Poulton, 1978b, Pl. I, fig. 1), overlying basal Jurassic (Sinemurian?)* (J) *coquina, in turn, unconformably overlying Permian sandstones (contact at hammer head, centre) (Norris, 1980a, Section 116 P13, GSC loc. C-85359). ISPG photo 2564-16.*

Figure 10.22. *Richly fossiliferous Bathonian to Lower Callovian concretionary siltstone and sandstone of the Richardson Mountains Formation* (JRM) *just north of Salmon Cache Canyon, Porcupine River (lat. 67°25′N, long. 137°47′W; Norris, 1980a, GSC loc. C-27140; Poulton, 1987). Porcupine River Formation sandstones* (JPO) *are faulted down against the Richardson Mountains Formation in the background. GSC photo 202910-H.*

sp. cf. *C. septentrionale* Frebold in shales lying below a white quartzite unit in Johnson Creek [the area contains two Johnson creeks; this reference is to the one south of Porcupine River]. Another contains *Cadoceras* (*Stenocadoceras*) sp. farther southwest in Keele Range (Poulton, 1978b, p. 463). A third (GSC loc. C-88278) contains Pliensbachian *Amaltheus*(?) in a rusty sandstone unit (Poulton, 1991). This last occurrence indicates the presence of the Almstrom Creek Formation (Poulton et al., 1982). The Molar YT-P-34 well (Fig. 10.1), in which Chamney (*in* Norford et al., 1971) identified Lower and Middle Jurassic rocks, is no longer thought to contain a thick succession of Jurassic rocks except, possibly, for a thin remnant of the Porcupine River Formation.

Except for the thin lower Husky tongue interpreted to be present by extrapolation from the northeast, the post-Bug Creek strata at Salmon Cache Canyon and Keele Range consist entirely of the Porcupine River Formation (Jeletzky, 1977). It reaches a maximum thickness of about 400 m near its type section at Salmon Cache Canyon. The Porcupine River Formation is entirely marine, and species of *Buchia* within it indicate that virtually all of the post-Lower Oxfordian Upper Jurassic is represented (Jeletzky, 1977). Dixon (1992) described the Jurassic strata of northern Eagle Plain area.

NORTHWESTERN AND WESTERN BASINAL SHALE AND SILTSTONE BELT

The Jurassic shales and siltstones of northwestern Yukon are lithologically similar to, and contain essentially the same faunas as, the Kingak Formation in northern Alaska described by Leffingwell (1919), Detterman et al. (1975) and others. They are recessive and poorly exposed in most places. Additionally, they were the preferred site of tectonic dislocation, resulting in severely contorted intervals with few marker horizons that can be used confidently to correlate between localities. In many places, sufficient ammonites and other fossils occur to permit correlation and recognition of the duplication and omission of strata. This is not the case in the northern Ogilvie Mountains however, where the presence of pre-Upper Oxfordian beds is not well documented by fossils in the Kingak Formation in most sections (Poulton, 1982).

Certain features of the Kingak Formation of northern Yukon also have been noted in northern Alaska by Detterman et al. (1975), and suggest the possibility of a widespread subdivision of this superficially monotonous unit. The lowest part is an extremely fissile black shale in Alaska. In the lower part, "*Pentacrinus*" occurs below *Amaltheus* in fissile clay-shale. The same relative distribution of these two fossils was recognized in the Loney Creek area of northern Yukon, where in addition, robust "*Pentacrinus*" forms thin beds within the succession yielding *Amaltheus*. A similar subdivision can be recognized also in the Bug Creek Group of Aklavik Range, where "*Pentacrinus*" is most common in the Upper Sinemurian Murray Ridge Formation (Poulton et al., 1982). The Murray Ridge Formation is a shale unit, softest and fissile at the base, with articulate crinoids like those at Loney Creek, indicating deposition in a regionally extensive, nonagitated, deeper water environment.

Detterman et al. (1975) noted that the upper part of their claystone and clay shale sequence contains beds and nodules that weather bright brick red, and that it is overlain by siltstone and silty shale with the most prolific ammonite and pelecypod fauna of the Jurassic of northeastern Alaska. Red weathering claystone concretions and beds also are particularly conspicuous and continuous in the Bajocian through Bathonian beds of northern Yukon, although discontinuous nodules also occur in other intervals. This interval in the coarser eastern facies contains abundant red weathering concretions and is richly fossiliferous in the Salmon Cache Canyon section (Poulton, 1978b, fig. 2; 1987).

Parts of the Kingak shale that contain *Buchia concentrica* (Sowerby) (Upper Oxfordian to Lower Kimmeridgian) are differentiated in some localities by the presence of large, buff weathering, siliceous, septarian lenses or concretions, and minor stellate nodules. These diagenetic features also characterize the equivalent Ringnes Formation of the Arctic Islands (Balkwill et al., 1977) and in places the lower part of the equivalent Husky Formation of northern Richardson Mountains.

Bonnet Lake–Johnson Creek area

A Lower Hettangian basal Kingak sandstone, 13 m thick, overlies Lower Carboniferous beds about 14.5 km north of Bonnet Lake (Frebold and Poulton, 1977; Fig. 10.23). The sandstone was identified at another locality nearby (Jeletzky, 1971, p. 205) and presumably extends throughout the Bonnet Lake area. The characteristic ammonites are *Psiloceras* sp. and *P.* (*Caloceras*) sp. cf. *P.* (*C.*) *johnstoni* (Sowerby) (Frebold and Poulton, 1977). The bivalves *Cardinia*

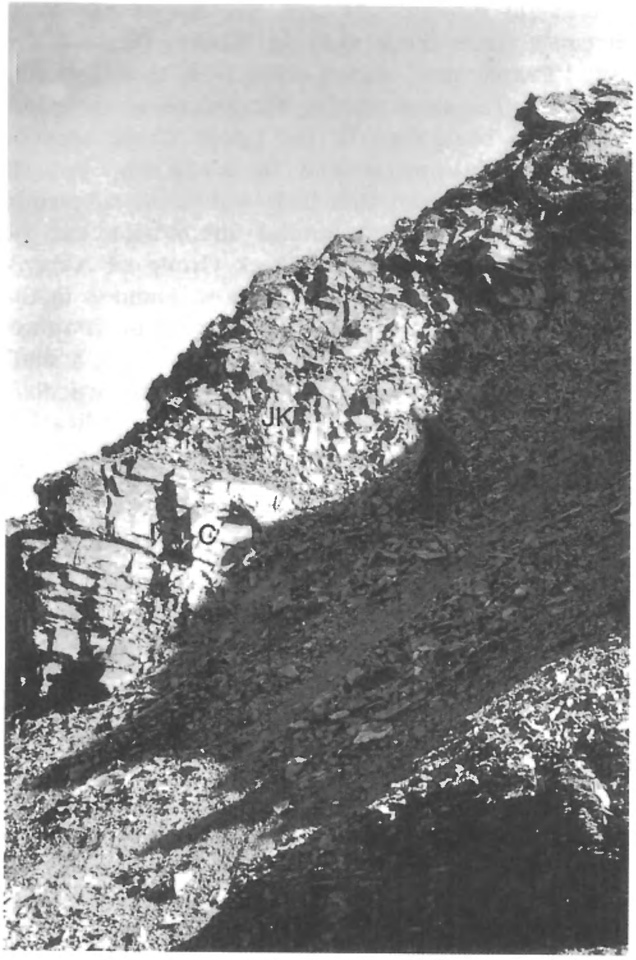


Figure 10.23. Lower Hettangian basal sandstone of the Kingak Formation (JK), *overlying Carboniferous sandstones* (C), *about 14.5 km north of Bonnet Lake (about lat. 68°20′N, long. 137°48′W; Norris, 1980b, GSC loc. C-38800). ISPG photo 2564–13.*

spp. and *Prosogyrotrigonia*(?) sp., which occur with the latter ammonites at the top of the sandstone unit, are not known to occur in rocks of other ages anywhere in the Arctic and therefore may be useful for indicating Hettangian beds in the northern Yukon. For this reason, sandstones with abundant *Cardinia* specimens at the head of Johnson Creek, north of Porcupine River (GSC loc. C–81332), are tentatively correlated with the basal sandstone north of Bonnet Lake (Poulton, 1982). The beds with *Cardinia*, collected in loose rubble, cannot be precisely located with respect to the layers of chert pebbles nor the base of the Jurassic nearby at the head of Johnson Creek, but are presumed to underlie an interval containing ferruginous oolite beds, phosphate nodules, and fossils, including "*Pentacrinus*". These last fossils resemble those from Sinemurian and Pliensbachian beds of the northern Richardson Mountains (Poulton et al., 1982). The top of the basal sandstone north of Bonnet Lake contains reworked phosphate nodules and other features indicating reworking during a hiatus that may be equivalent to the phosphatic interval nearby at Johnson Creek. At the head of Johnson Creek, grit layers continue upward a short distance within a concretionary black shale unit which contains in its lower part "*Pentacrinus*" and "*Pleurotomaria*" and is thus homotaxial with the basal Murray Ridge Formation of the Richardson Mountains (Poulton et al., 1982).

The younger shales in the area contain Late Pliensbachian (*Amaltheus* spp.), Toarcian (*Pseudolioceras* spp., *Dactylioceras* spp.), Aalenian [*Leioceras* sp. aff. *L. opalinum* (Reinecke), *Pseudolioceras* sp. aff. *whiteavesi* (White), *Erycitoides howelli* (White)], Lower Bajocian (*Arkelloceras* sp.), Bathonian(?) (*Arctocephalites*?), and Callovian (*Cadoceras* sp.) ammonites. Many of these were listed by Poulton (1978b, 1991). Neither the completeness nor thickness of the succession or of zones within it can be accurately judged because of structural deformation, intermittent exposure, and the absence of distinctive marker units. However, the estimate of 600 m or more (Jeletzky, 1975, fig. 8, sec. G1) of pre-Upper Oxfordian Jurassic rocks is reasonable.

At other localities in the vicinity of Bonnet Lake, the sequence is even less well understood because of poor exposures and tectonic complications. The best exposures lie nearby, to the southeast along the upper parts of Johnson Creek, where basinward pinchouts of the eastern siltstone and sandstone units occur. Some coarsening-upward cycles in the order of 30 to 60 m thick are rich in *Gryphaea* shells (Poulton, 1988a, 1991). These shoal deposits presumably represent approximately the same events indicated by *Gryphaea* beds at the base of the Bug Creek Group in the northwestermost sections of the northern Richardson Mountains (Section PU–19–76 of Poulton et al., 1982).

The westernmost occurrences of the Anne Creek sandstone member (Manuel Creek Formation) of the northern Richardson Mountains (Poulton et al., 1982) are present at several localities in the upper headwaters of Johnson Creek (Fig. 10.24). Here it forms the top of a coarsening-upward sequence which is rich in *Erycitoides* and other Aalenian ammonites and bivalves (Poulton, 1982, 1991). Just west of the locus of the main splay of the Kaltag Fault zone, these occurrences firmly tie the sequence paleogeographically to the pericratonic Bug Creek succession.

Other minor sandstone units occur higher in the succession in the vicinity of Bonnet Lake and the head of nearby Johnson Creek, but most are not firmly dated. At least one of them resembles the Waters River Member of the western Richardson Mountains (Poulton et al., 1982) and contains abundant belemnites and *Inoceramus*; another contains *Buchia concentrica*, and represents the Porcupine River Formation (Jeletzky, 1977). Jeletzky (1974, p. 21) also found *Buchia* cf. *concentrica* in a siltstone and sandstone interval below the main sandstone unit identified as the Porcupine River Formation northwest of Bonnet Lake. Beds at the head of Johnson Creek, higher than the sandstone with *Buchia concentrica* and below the Valanginian quartzites, are shales and siltstones, with large yellow weathering siliceous concretions and laminated sandstones that exhibit abundant grooves and tool marks characteristic of their prodeltaic setting.

Figure 10.24. *Coarsening-upward, probable barrier-island sequence, Aalenian Anne Creek Member of Manuel Creek Formation in its westernmost exposure, on Johnson Creek (lat. 68°03′N, long. 137°54′W, at or near Norris, 1980b, GSC loc. C-88097). ISPG photo 2445–10.*

Northern Ogilvie Mountains

Kingak siltstones with softer shale and harder sandstone intervals occupy the recessive intervals between Late Paleozoic rocks below and Valanginian quartzites above, in the northern Ogilvie Mountains and adjacent Keele Range (Figs. 10.25–10.27). Several sections have been described previously by Jeletzky (1971, 1972b, 1975). The Kingak Formation becomes thinner toward the south within this outcrop belt (Fig. 10.6).

Some Lower Jurassic beds are present in the very soft, strongly bioturbated siltstone in the northern Ogilvies. D.H. McNeil (pers. comm., 1979) identified

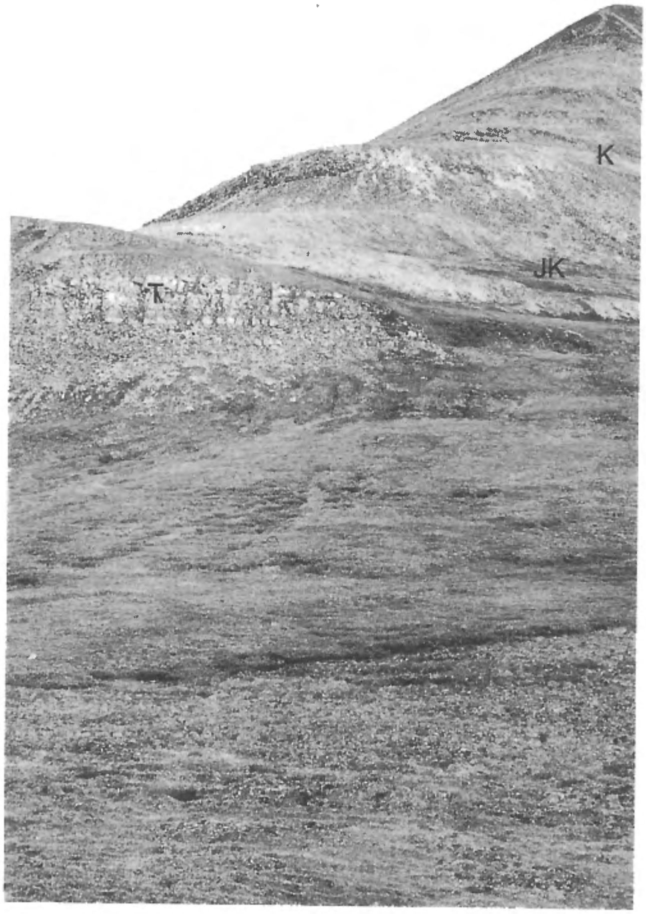


Figure 10.25. *Probable Jurassic (not dated directly) shales (*JK*; recessive interval above lowest bluffs) overlying resistant Triassic limestones (*TR*), the southernmost Jurassic exposure in northern Yukon (lat. 65°42′10″N, long. 140°22′W). The middle and upper resistant units in the upper part of the photo are coal-bearing Lower Cretaceous sandstones and contain the bivalve* ***Buchia*** *(K) (Norris, 1976, 1981a, Section 116 F14; Jeletzky, 1971, p. 218, 219). ISPG photo 1225–5.*

Figure 10.26. *Jurassic Kingak shales (*JK*; center), grading up into Late Jurassic Porcupine River sandstones (*JPO*; skyline), between Bern Creek and Grayling Fork, northern Ogilvie Mountains (lat. 66°12′45″N, long. 140°39′W). ISPG photo 2564–11.*

several genera of Foraminifera from a sample taken 55 m above the base of the Kingak Formation (GSC loc. C–81373). While most genera are not useful for a detailed age determination, for one he stated: "*Pseudonodosaria* sp. compares closely with *P. turbinata* (Terquem and Berthelin) figured from Lower Jurassic rocks of the Arctic Slope by Tappan (1955, Pl. 26, fig. 10)." From a sample taken 75 m above the base at the same locality (GSC loc. C–81375), he identified *Haplophragmoides* sp. and *Conorbina* sp. He stated: "*Conorbina* sp. compares closely with a similar, but unpublished, species which occurs in the Upper Jurassic on Martin Creek, N.W.T."

At two localities, the basal units are coarse clastic rocks. At the more northerly of these two localities, between Salmon Fork and Drifting Snow Creek (Fig. 10.1), at least 9 m of magnetite and hematite oolite (Fig. 10.28; Norris, 1976, p. 461; 1981b; GSC loc. C–92521; Chapter 14) overlie undated sandstones above the Paleozoic carbonates and below the Kingak siltstone with which its contact is covered. At the other locality, at the head of Fishing Branch, where the section was previously described by Jeletzky (1971, p. 214), 65 m of siltstone and sandstone overlie Triassic siltstones, and underlie argillaceous siltstones and shales in which *Buchia concentrica* occurs about 400 m above the base of the Jurassic. The basal metre of the Jurassic section is conglomeratic; ferruginous oolites occur in higher beds (op. cit.). The oolite beds at both localities are questionably dated as earliest Early Jurassic, based on their tentative correlation with those at the head of Johnson Creek, south of Bonnet Lake, described above.

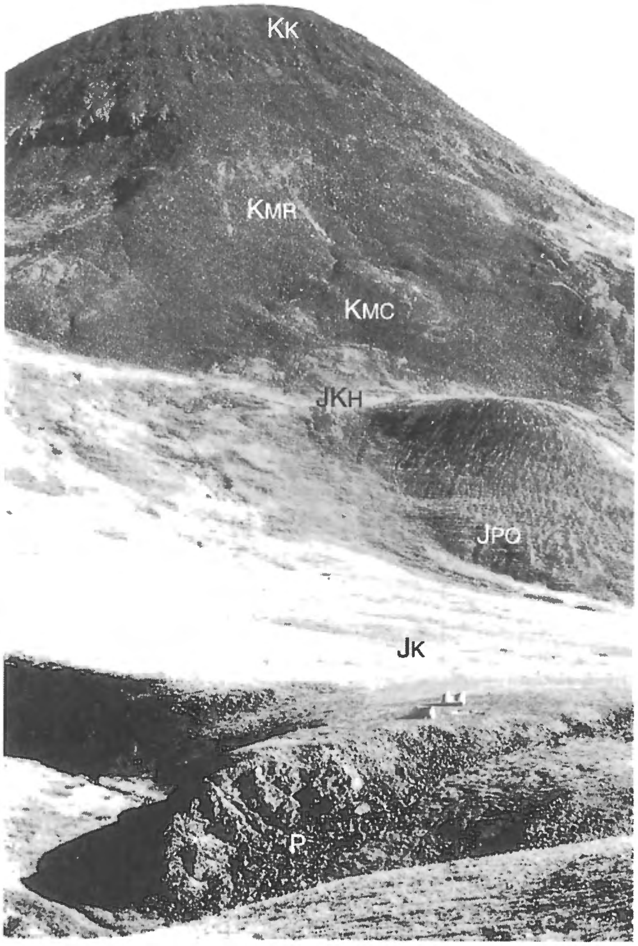


Figure 10.27. *Recessive Jurassic Kingak shale (*JK*), lying unconformably on Carboniferous or Permian chert (*P*; contact at tent camp), and overlain successively by: Late Jurassic Porcupine River Formation sandstone (*JPO*; small ridge, centre right); a recessive interval containing Berriasian–Valanginian Husky Formation shale (*JKH*), Martin Creek (*KMC*) and McGuire (*Km*) formations; and resistant Valanginian beds of the Kamik sandstone (*KK*; skyline), northern Ogilvie Mountains (lat. 66°25′30″N, long. 140°24′W). ISPG photo 2564–10.*

Jeletzky (1972a, b, 1975) identified the belemnite *Acrocoelites* at several localities from the recessive interval below the beds that contain *Buchia concentrica*, dated them as Middle Toarcian to Aalenian (J.A. Jeletzky, pers. comm., 1976), and interpreted the relationships to indicate thinning and fining southward into a starved basin away from a land area to the north, during Jurassic time. The lower beds in these sections are not sufficiently well dated to document these facies variations and revised interpretations (Poulton, 1982) suggest southward and

Figure 10.28. Basal Kingak hematite and magnetite oolite, northern Ogilvie Mountains (lat. 66°31′15″N, long. 140°15′W; Norris, 1976, p. 461; 1981b, loc. C-92521). ISPG photo 2564-9.

Figure 10.29. Bathonian shales and siltstones of the Kingak Formation, 2 km northeast of Old Crow, on Old Crow River (lat. 67°36′15″N, long. 139°46′W). The upper half of the bluffs is composed of Tertiary or Quaternary gravels that partly obscure the shales below them. ISPG photo 2564-15.

presumably eastward overlap of the older Jurassic rocks by the Husky Formation or its equivalent. This conforms with the meager paleontological control that is reasonably precise and certain, and with extrapolation of the southeastward overlap relationship that is well documented in the northern Richardson Mountains, northeastward along depositional strike. It is also substantiated by the similarities of lithologic details (such as the character of concretions) of these poorly fossiliferous rocks with those in the Husky Formation and equivalent beds elsewhere in northern Yukon and adjacent Northwest Territories, and their differences from older beds regionally (Poulton, 1982).

Rubbly, argillaceous, physiographically indistinct sandstone units represent thin, distal parts of the Porcupine River Formation along the entire length of the northern Ogilvie Mountains (Jeletzky, 1972b, 1977). They contain well developed hummocky cross-stratification and bivalve-rich layers (J. Dixon, pers. comm., 1991).

Old Crow

Outcrops of concretionary shale and siltstone, 1.6 to 2 km north of the mouth of Old Crow River (Fig. 10.29), contain Bathonian *Arctocephalites* spp. (Frebold *in* Poulton, 1978b, p. 462). D.K. Norris found Late Bathonian shales with *Arcticoceras* sp. along Caribou Bar Creek and the next creek to the west. These occurrences suggest that Middle Jurassic argillaceous rocks underlie or underlay the entire region of northwestern Yukon, over most of which area they have been eroded. The relationships to older and younger rocks at these localities cannot be judged because of inadequate exposure. Jeletzky (1972b, p. 45, 46) described the first outcrop as sandy to very sandy, and interpreted it (Jeletzky, 1972b, 1975) as a westerly derived facies, marginal to a western landmass. However, the strata are not rich in sandstone and Poulton (1982) suggested that the Bathonian siltstones here probably represent a basinward, shelf facies of the equivalent craton-derived sandstones to the east.

Babbage River area

At several localities in the Babbage River area, discontinuous faulted and folded exposures of the Kingak Formation occur in low areas between ridges formed by the Carboniferous Lisburne Group carbonates below and Lower Cretaceous quartzites above (Fig. 10.30). The Upper Jurassic Porcupine River sandstone does not occur this far north and the Berriasian and Valanginian Martin Creek and Kamik sandstones are sporadic here. The Upper Oxfordian to Kimmeridgian interval, identified by the presence of *Buchia concentrica*, is characterized by large, buff weathering, septarian siliceous lenses. Lower parts of the Kingak Formation contain a variety of different concretionary types; hard, red weathering concretions forming semi-continuous bands are particularly characteristic of the Upper Bajocian and Bathonian beds. The lower part of the Kingak Formation in this area is invariably very poorly exposed, the lowest 400 m or so above the Lisburne Group or a thin

Figure 10.30. *Upper Oxfordian or Lower Kimmeridgian Kingak shale with* ***Amoeboceras,*** *Babbage River near Trout Lake (approximately lat. 68°48′N, long. 138°43′W). ISPG photo 2564–8.*

Triassic Shublik sandstone is generally entirely covered, and where exposed, does not yield fossils. Diagnostic fossils from the Babbage River drainage area include: *Erycitoides* sp. cf. *E. howelli* (White), *Pseudolioceras* sp. cf. *P. whiteavesi* (White) (both Aalenian), *Arctocephalites*(?) or *Cranocephalites*(?) sp., *Arcticoceras* sp. (Bathonian), *Cadoceras* sp. aff. *barnstoni* (Meek) (Upper Bathonian), *Cadoceras arcticum* Frebold, *C.* (*Stenocadoceras*) sp. cf. *C. canadense* Frebold, *Phylloceras bakeri* Imlay (Lower Callovian), *Cardioceras* sp. aff. *C. cordatum* (Sowerby), *C.* sp. aff. *C. alphacordatum* Spath (Lower Oxfordian), and *Amoeboceras* and *Buchia concentrica* (Upper Oxfordian and Lower Kimmeridgian) (Frebold et al., 1967; Poulton, 1978b). The youngest diagnostic fossils found in the recessive unit below the regionally widespread, bluff-forming Lower Cretaceous quartzites are probably Valanginian *Buchia* sp. cf. *B. keyserlingi* (Lahusen) and *B.* sp. cf. *B. inflata* (Toula) identified by Jeletzky (GSC loc. C–53438). These species characterize the McGuire Formation in the northern Richardson Mountains, which is not separated from older shales by any significant sandstone formations in the Babbage River area.

Firth River and Spring River area

A thick interval of shales and siltstones with Upper Pliensbachian *Amaltheus stokesi* (Sowerby), *A. bifurcus* Howarth and various Lower Toarcian ammonites, including *Pseudolioceras* spp. and *Dactylioceras* sp., occurs along Loney Creek and a southern tributary (Frebold et al., 1967; Frebold, 1975, p. 18; Poulton, 1978b, p. 458–459; Fig. 10.31). More recent discoveries of Pliensbachian *Lytoceras* sp. with *Amaltheus*, and Toarcian *Ovaticeras* and *Collina*(?) are described by Poulton (1991). Similar shales directly overlie Upper Triassic sandstones and limestones, although the lower 60 m of the shale succession have not yielded age diagnostic fossils. Laminated siltstones, within which *Amaltheus* occurs, bear grooves and other sole markings indicative of turbidite deposition at one locality, and nearby contain layers of articulated crinoids indicating deposition below wave base. *Amaltheus*(?) and several Toarcian ammonites have been found close together in the sheared northernmost outcrops along the west bank of Firth River: *Ovaticeras* sp. cf. *O. propinquum* and *Catacoeloceras*? sp. identified previously by H. Frebold (GSC loc. C–53497), and *Catacoeloceras*? sp. cf. *C. spinatum*, *C.* sp. cf. *C. polare*, and *Eleganticeras*? identified by R.W. Imlay (Poulton, 1978b, p. 459). The locality from which Callovian ammonites were reported (O'Neill, 1924) has not been rediscovered.

To the east, black concretionary Kingak shales directly overlie Precambrian (?) or Lower Paleozoic rocks, as part of a northeastward overstepping succession that also involves the overstepping of Paleozoic rocks by the Triassic farther southwest (Norris, 1974, p. 35). Pre-Jurassic erosion has, therefore, removed equivalents of the Prudhoe Bay Permian and Triassic reservoir rocks, although the structural high onto which the overstepping took place may well be a continuation of the same Arctic Platform or Barrow Arch which lay to the north of Alaska. Only the lowermost beds of the Kingak are exposed here, and their age is not known because no fossils of any kind have been recovered from them, although nearby similar shales were dated as Late Jurassic by Chamney (*in* Norris, 1972).

Figure 10.31. *Pliensbachian beds with* ***Amaltheus*** *and articulated crinoids in Kingak Formation shale, Loney Creek near the mouth of Firth River (lat. 69°21′05″N, long. 139°38′45″W). ISPG photo 2564–5.*

BIOSTRATIGRAPHY AND PALEONTOLOGY

Ammonites, although generally sparsely distributed and commonly poorly preserved, are nevertheless sufficiently abundant to indicate the ages and correlations of the major Lower Jurassic through Oxfordian stratigraphic units. They have been of paramount importance in the preparation of this stratigraphic compilation. The significant ammonites are listed in Table 10.2. The age determinations are based primarily on comparison of the ammonites with those of northwestern Europe and eastern Greenland, where their succession has been established. Only at rare localities, such as at Salmon Cache Canyon on the Porcupine River (Poulton, 1978b, fig. 2; 1987), is there a succession of well preserved ammonites good enough to serve as a standard for a local zonation. Several reports on the Jurassic fossils have appeared (Frebold, 1960, 1961, 1964a, b, 1975; Frebold et al., 1967; Frebold and Poulton, 1977; Ager and Westermann, 1963; Poulton, 1987, 1991), but many of them, particularly the nonammonite faunas, are still not completely known and research is in progress.

Table 10.2

List of guide ammonites and buchias. Both international standard zones (species names capitalized) and local zones (with genus names) are shown

HETTANGIAN

Planorbis Zone: *Psiloceras* sp. cf. *P.* (*C.*) *johnstoni* (Sowerby), *Psiloceras* spp.

SINEMURIAN

Bucklandi Zone: *Coroniceras* sp.
Semicostatum Zone: *Arnioceras* sp. cf. *A. douvillei* (Bayle)
Oxynotum Zone: *Oxynoticeras oxynotum* (Quenstedt), *Gleviceras* sp. *Aegasteroceras* (*Arctoasteroceras*) *jeletzkyi* Frebold, *Aegasteroceras* sp.
Raricostatum Zone: *Echioceras aklavikense* Frebold

PLIENSBACHIAN

Margaritatus Zone: *Amaltheus stokesi* (Sowerby), *A. bifurcus* Howarth

TOARCIAN

Tenuicostatum Zone(?): *Ovaticeras* sp. cf. *O. ovatum* (Young and Bird), *Collina*(?) sp. aff. *C.*(?) *simplex* Fucini
Bifrons Zone(?): *Dactylioceras commune* (Simpson)
Thouarsense Zone(?): *Peronoceras* sp. cf. *P. polare* (Frebold), *Pseudolioceras lectum* (Simpson), *Pseudolioceras* sp.

AALENIAN

Opalinum Zone(?): *Leioceras* sp. aff. *L. opalinum* (Reinecke), *Tmetoceras* sp.
Erycitoides howelli Zone: *E. howelli* (White), *Pseudolioceras* sp. aff. *P. whiteavesi* (White), *Planammatoceras* sp.

BAJOCIAN

Arkelloceras tozeri Zone: *Arkelloceras tozeri* Frebold, *A. maclearni* Frebold, *A. elegans* Frebold
Borealis Zone: *Cranocephalites borealis* (Spath), *C. warreni* Frebold

BAJOCIAN or BATHONIAN

Indistinctus Zone: *Cranocephalites indistinctus* Callomon
Pompeckji Zone: *C. pompeckji* (Madsen), *C. maculatus* Spath, and *C. vulgaris* Spath

BATHONIAN

Arctocephalites spathi Zone: *A. spathi* Poulton, *A.* sp. cf. *A. ellipticus* Spath
Arctocephalites porcupinensis Zone: *A. porcupinensis* Poulton, *A.* sp. aff. *A. sphaericus* Spath, *A. callomoni* Frebold, *A.* sp. aff. *nudus* Spath
Arctocephalites amundseni Zone: *A. amundseni* Poulton, *A.* sp. aff. *A. sphaericus* Spath, *A. porcupinensis* Poulton, *A. callomoni* Frebold, *A.* sp. aff. *A. nudus* Spath, *A. praeishmae* Poulton, *A. arcticus* (Whitfield), *A. kigilakhensis* Voronetz, *Iniskinites* sp.
Arctocephalites frami Zone: *A. frami* Poulton, *A.*(?) *belli* Poulton, *Arcticoceras* sp., *Kepplerites* sp., *Iniskinites* sp.
Ishmae Zone: *Arcticoceras ishmae* (Keyserling), *A. harlandi* Rawson, *Arctocephalites*(?) *belli* Poulton, *Loucheuxia bartletti* Poulton, *Kepplerites* sp., *Iniskinites* sp., *Cadomites* sp., *Oxycerites birkelundi* Poulton, *Parareineckeia* sp., *Choffatia*(?) sp.
Cadoceras barnstoni Zone: *C. barnstoni* (Meek), *C. variabile* (Spath), *Paracadoceras* sp., *Loucheuxia bartletti* Poulton, *Kepplerites* sp. aff. *K. rosenkrantzi* Spath, *Iniskinites variocostatus* (Imlay), *I. yukonensis* Frebold, *Cadomites* sp.

CALLOVIAN

Cadoceras bodylevskyi Zone: *Cadoceras bodylevskyi* Frebold
Athleta Zone: *Longaeviceras* sp. cf. *L. stenolobum* (Keyserling), *Grossouvria*

OXFORDIAN

Mariae Zone: *Cardioceras* spp. sp. aff. *C. scarburgense* (Young and Bird)
Cordatum Zone: *Cardioceras alphacordatum* Spath, *C.* sp. aff. *C. distans* (Whitfield), *C.* sp. cf. *C. hyatti* Reeside
Densiplicatum Zone: *Cardioceras* (*Maltoniceras*) sp.
Glosense Zone: *Amoeboceras*(?) sp.
Serratum Zone: *Amoeboceras* (*Prionodoceras*) sp.
Rosenkrantzi Zone: *Amoeboceras* sp., *Buchia concentrica* (Sowerby)

OXFORDIAN–KIMMERIDGIAN

Buchia concentrica Zone: *B. concentrica* (Sowerby)

KIMMERIDGIAN–TITHONIAN

Buchia mosquensis Zone: *B. mosquensis* (von Buch)

TITHONIAN/VOLGIAN

Buchia piochii Zone: *B. piochii* (Gabb)
Buchia fischeriana Zone: *B. fischeriana* (d'Orbigny)

In the Upper Jurassic, biostratigraphic control is established mainly by species of the boreal bivalve *Buchia* (Jeletzky, 1960, 1967, 1971, 1972a, b, 1974, 1975, 1977, 1980).

Other macrofossils also serve to identify gross biostratigraphic packages and provide interbasinal correlations. Some of them have approximately the same time ranges in the Kingak Formation of northwestern Yukon and Alaska (Detterman et al., 1975). The lowest appearance of belemnites and *Inoceramus* is in Toarcian beds. Individual species of *Inoceramus* (*Retroceramus*) probably can be differentiated biostratigraphically to approximately the level of the stage. However, until further taxonomic studies are done, no detailed biostratigraphic subdivision of the genus can be given. Like the belemnites, *Inoceramus* is very rare in the Aklavik Formation because of its facies, and does not reappear until higher in the Cretaceous succession, above the *Buchia*-dominated faunas. Rich and varied faunas with abundant bivalves, gastropods, brachiopods and "*Pentacrinus*" occur in beds of Toarcian and older Jurassic ages, while younger Jurassic shelly faunas are dominated by belemnites and the bivalves *Inoceramus, Oxytoma,* and *Meleagrinella*. Small scaphopods litter many beds in the upper part of the Richardson Mountains Formation (Bathonian to Lower Oxfordian) and also appear less commonly in the Aklavik and Porcupine River formations.

Most of the macrofauna are closely similar to those of the Canadian Arctic Islands, eastern Greenland, and northern Eurasia. They differ from contemporaneous faunas in more southerly parts of western Canada in the boreal character of most of the Middle and Upper Jurassic ammonites, the lesser diversity of other groups present, and the near absence of certain characteristically southern faunal elements, such as trigoniid bivalves.

The eight zones established in the exceptionally fossiliferous Bathonian and Lower Callovian section at Salmon Cache Canyon (Poulton, 1987) are based on the dominant boreal ammonite family Cardioceratidae, which is represented here by a succession of *Arctocephalites, Arcticoceras,* and *Cadoceras*. Associated ammonites include: some of Pacific affinity, such as *Iniskinites*; some that are more cosmopolitan (but not boreal), such as several genera of phylloceratids, *Oxycerites*, and others; and one that is endemic, *Loucheuxia*. The mixture of different faunal realms represented is explained by the position of the Salmon Cache Canyon section at the northwestern corner of the Jurassic North American craton, where northern and southern water masses might have come in contact (Fig. 10.32).

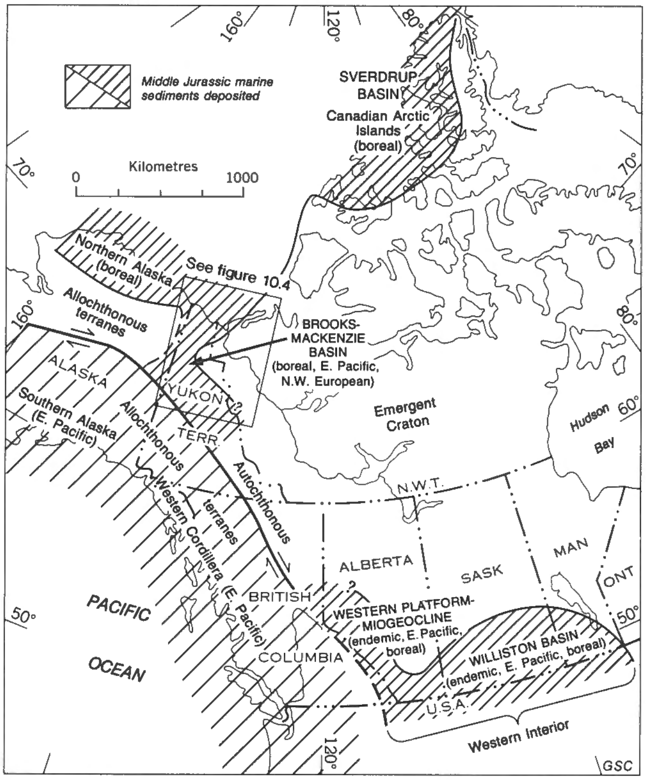


Figure 10.32. *Configuration of marine sedimentary basins and major tectonic features of the Middle Jurassic of western Canada, showing basic paleobiogeographic affinities of the Upper Bathonian ammonites.*

Only the eastern parts of northern Richardson Mountains, the Mackenzie Delta, and the Salmon Cache Canyon areas have yielded significant recovery of microfauna and microflora, both of which are more commonly poorly preserved. The majority of the microfossils recovered are long-ranging forms of little biostratigraphic value as individuals, but they characterize the stratigraphic units as associations.

Agglutinated Foraminifera dominate the Lower and Middle Jurassic microfaunal assemblages. The succession can be roughly subdivided by Foraminifera into four biostratigraphic assemblages which approximate the duration of a stage, although many species occur in more than one of these assemblages. They are approximately Sinemurian, Toarcian to Aalenian, Bathonian, and Callovian to Oxfordian. Many of the species are figured by Leskiw (*in* Poulton et al., 1982).

Regarding Foraminifera from the northern Ogilvie Mountians, D.H. McNeil (pers. comm., 1980) noted:

> The foraminifers recovered from the sampled Kingak Formation are generally poorly preserved

and covered with a pervasive black coating which restricts identification.

Two foraminifers noted above, *Pseudonodosaria* sp. (C-81374) and *Conorbina* sp. (C-81378), suggest a Jurassic age by tenuous comparisons with known Jurassic assemblages of the Arctic. More refined conclusions cannot be drawn considering the poor preservation of the material at hand.

Only one ostracod specimen was found, an undetermined genus, in probable Bathonian beds of the Richardson Mountains Formation. The radiolarian *Eucyrtidium* sp. occurs abundantly in the Toarcian upper part of the Almstrom Creek Formation and the Manuel Creek Formation (Leskiw *in* Poulton et al., 1982). A prolific and varied Upper Jurassic microfauna occurs in the Husky Formation (Hedinger, 1993).

The Lower and Middle Jurassic samples contain generally low amounts of spores, pollen and dinoflagellates. The preservation is extremely poor at most localities, perhaps in part due to a high-energy environment of deposition, but largely a result of post-depositional carbonization. Those forms that have been described previously from the Arctic Islands, the northern Yukon and adjacent Northwest Territories, Alberta and Saskatchewan bear little resemblance to the Brooks–Mackenzie palynomorphs. Most of the palynomorphs are long ranging but others with more restricted ranges are useful tools for correlating the Bug Creek Group. They were listed and some were figured by Audretsch (*in* Poulton et al., 1982). Intense carbonization had been thought to characterize all localites near and west of the Yukon/Northwest Territories border, but a regional compilation of thermal maturation data (Davies and Poulton, 1989) suggests that local pockets to the west might yield useful samples. Those from the Upper Jurassic Husky Formation of the Aklavik Range are well preserved, varied and amenable to relatively fine zonation (Fensome, 1987).

Samples of siltstone from the Kingak sections of northern Ogilvie Mountains, collected for micropaleontological and palynological examination, proved disappointing, like nearly all others in the Kingak Formation west of the Yukon/Northwest Territories border. Regarding palynomorphs, N.S. Ioannides (pers. comm., 1980) commented:

> Palynomorphs are highly carbonized and their structure completely altered. With the exception of bisaccate pollen (Carboniferous - present) and reworked *Densosporites* sp. (Carboniferous) identified by their distinctive outlines, all other microfossils remain unidentified. Modern contaminants are also observed.

HISTORICAL SUMMARY

The oldest Jurassic beds recognized are Early Hettangian basal sandstones of the Kingak Formation near Bonnet Lake (Frebold and Poulton, 1977). Associated strata include ferruginous oolites (Fig. 10.33). No Upper Hettangian fossils are known. To the east, the basal beds are Sinemurian—probably Lower Sinemurian in western and perhaps also central parts of the northern Richardson Mountains (Poulton et al., 1982), and Upper Sinemurian in their eastern parts (Jeletzky, 1967)—suggesting progressive transgression of the craton. The basal units in these areas are locally derived shallow-water marine sandstones that thus become younger eastward and are

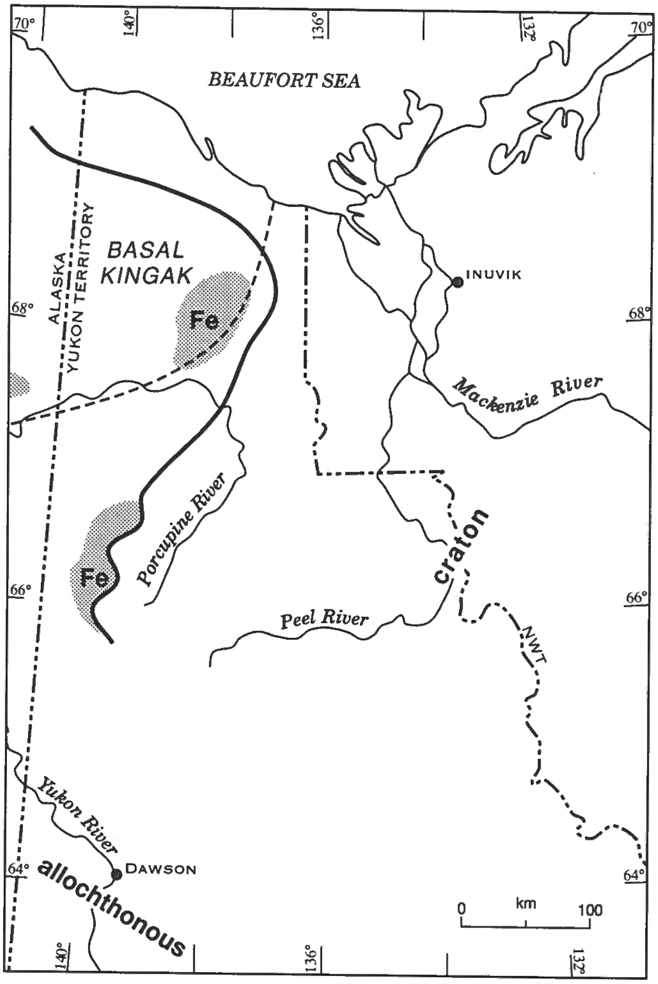


Figure 10.33. Distribution of Hettangian rocks. "Fe" indicates ferruginous oolite deposits. The dashed line through northern Yukon in Figures 10.33–10.37 indicates the position of the so-called "Kaltag Fault" for reference.

conglomeratic at their southeastern depositional limit (Scho Creek Member, Poulton et al., 1982). The presence of ferruginous oolites at the base of the Kingak Formation in the northern Ogilvie Mountains to the southwest suggests, by analogy with the succession in the Bonnet Lake area, that Hettangian beds may be present there also, but they are not dated by fossils directly.

In the northern Richardson Mountains, Upper Sinemurian beds above the basal conglomerate or lag are in a shale-siltstone facies of essentially uniform thickness (Murray Ridge Formation of Poulton et al., 1982) which contains *Echioceras*. Articulated crinoids indicate deposition below wave base. The small thickness variation indicates an essentially planar bottom surface there at that time. The basal units at Salmon Cache Canyon along Porcupine River are also probably Early Sinemurian in age.

No Lower Pliensbachian fossils have been recognized.

Amaltheus indicates the presence of Upper Pliensbachian beds in the Kingak shales in Bonnet Lake (Jeletzky, 1974; Poulton, 1978b) and Firth River (Frebold et al., 1967) areas. In the Firth River area, articulated crinoids and turbidites occur in the beds which contain *Amaltheus*. Equivalent beds in the northern Richardson Mountains are the Almstrom Creek Formation, a thick prograding shallow-water marine shelf sandstone unit presumably derived from the southeast (Poulton et al., 1982). No source direction has been identified for the turbidites in the Firth River area but they could be derived from either a northern, offshore source upland, or from the Almstrom Creek sand complex to the southeast, bypassing the Bonnet Lake area which contains no such coarse clastic material in rocks of the same age.

The Almstrom Creek shelf sandstone in the northern Richardson Mountains was transgressed, through continued subsidence and reduced sediment supply, by shales and siltstones of the Manuel Creek Formation, which contains Toarcian and Aalenian ammonites (Poulton et al., 1982). The Manuel Creek Formation becomes coarser grained upward, culminating in the development of Aalenian offshore bars, or perhaps shoreline, deposits in the western part of the northern Richardson Mountains (Anne Creek Member). This indicates a period of widespread regression succeeded by an unconformity. Beds in the Kingak shale equivalent to the Manuel Creek Formation have been identified by ammonites in Firth River, Babbage River, and Bonnet Lake areas to the west (Poulton, 1978b, 1982).

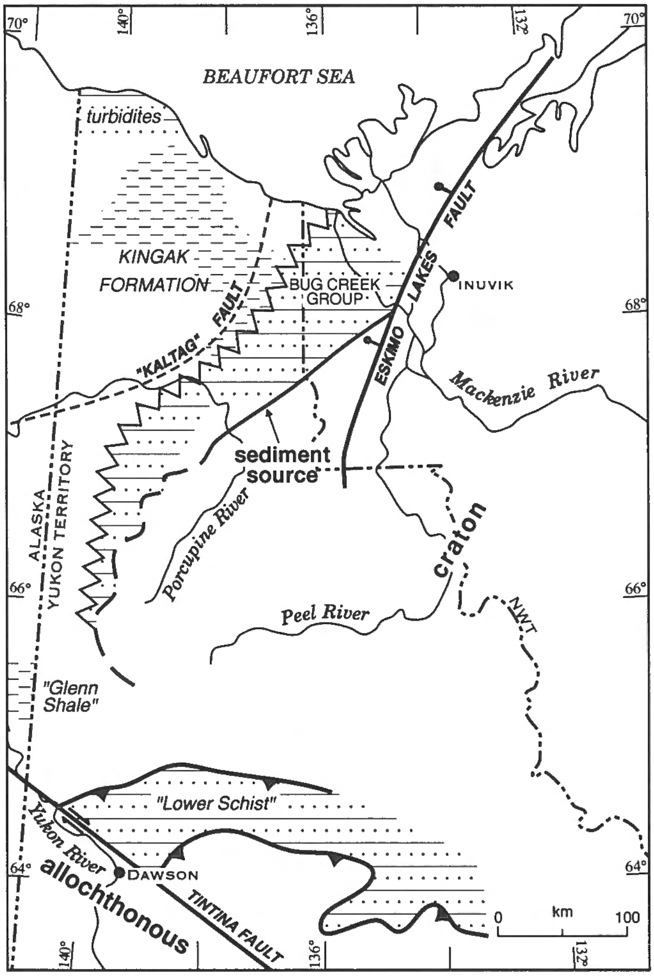


Figure 10.34. Generalized facies distribution map for Sinemurian to Toarcian strata. "Lower Schist" in Figures 10.35–10.37 is a Jurassic unit involved in northward thrusting in central Yukon (Poulton and Tempelman-Kluit, 1982).

All these Lower Jurassic rocks (Figs. 10.17, 10.34) thin southeastward, and their present southeastern preservational limit coincides with the Eskimo Lakes Fault Zone in the Mackenzie Delta, and with a line joining McDougall Pass and the mouth of Bell River in the Richardson Mountains. The present southeastern limit of these rocks is partly controlled by pre-Early Bajocian erosion associated with the Aalenian regional regressive phase and perhaps also associated with activity on local uplifts south of McDougall Pass (Rat Uplift) and in White Mountains area (White Mountains Uplift). These last periods of uplift are documented by Middle Jurassic strata directly overlying Paleozoic beds (Jeletzky, 1967; Poulton and Callomon, 1976; Poulton et al., 1982).

The period of stillstand preceding renewed transgression in the Bajocian, together with the transgression itself, resulted in deposition of a basal transgressive sandstone with phosphatic layers in its lower 1 m, in low areas in much of the northern Richardson Mountains (Little Bell Member). The base of the transgressive sandstone is Early Bajocian in the central parts of northern Richardson Mountains, Late Bajocian in the eastern (Jeletzky, 1967) and southern parts, and over a small uplift on the unstable shelf (White Mountains Uplift; Poulton and Callomon, 1976). This indicates gradual southeastward transgression, which extended southward in the northern Richardson Mountains beyond the limits of older Jurassic rocks (Figs. 10.18, 10.35).

The overlying strata form a clastic wedge that becomes thicker and finer grained northwestward in the Richardson Mountains (Richardson Mountains Formation). Local conditions on the shallow shelf resulted in a localized concentration of sandstone bodies at different intervals from place to place. Equivalent beds in the Kingak shale farther west have been identified by Bathonian through Early Oxfordian fossils in Babbage River and Old Crow areas (Frebold et al., 1967; Poulton, 1978b), and are assumed to be widespread.

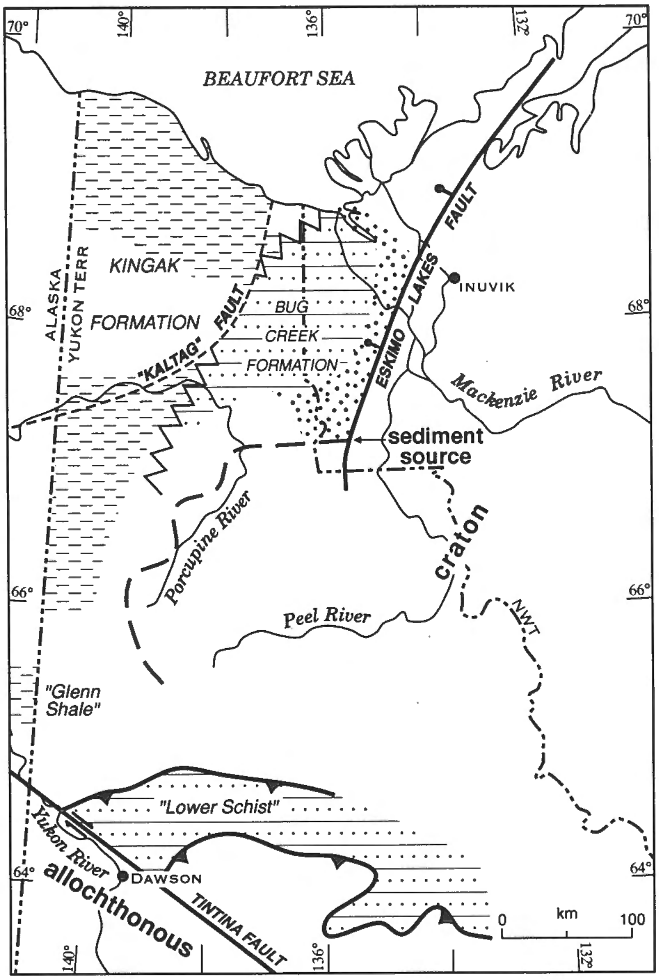


Figure 10.35. Generalized facies distribution map for Middle Jurassic strata.

In western parts of northern Richardson Mountains, just to the west of White Mountains Uplift and approximately contemporaneous with its development, the Waters River depocentre (Poulton et al., 1982) became the site of an unusually great thickness of Middle Jurassic clastic rocks. They are predominantly shales and siltstones, but at some times significant localized sandstone bodies were deposited. The Waters River Member for example, appears to comprise a pile of offshore bars (Poulton et al., 1982).

The upper part of the Bug Creek Group succession and the overlying Aklavik Formation (Poulton et al., 1982) are a coarsening-upward succession that represents a prograding shallow-water marine sandstone blanket of Early Oxfordian age. It is widespread in the northern Richardson Mountains.

Late Oxfordian and younger Jurassic rocks are dominated by shale of the Husky Formation (and equivalent strata in the Kingak Formation), with a major sandstone unit, the Porcupine River Formation (as well as the North Branch Formation), in the south and southeast (Figs. 10.36, 10.37). They were deposited eastward, southeastward and northeastward, beyond the limits of the older Jurassic rocks.

All the sandstones of the southeastern basin-marginal arenaceous belt extend basinward to the vicinity of the western edge of the northern Richardson Mountains and Bonnet Lake. They disappear there by shaling-out into the Kingak Formation and were apparently derived from southerly migrating points to the east and southeast (Figs. 10.34–10.37).

Deposition of each of the progradational regressive packages was preceded by cratonward trangressions which are remarkable for the consistency with which progressive onlap can be seen in the preserved record. The depocentres of the Lower, Middle and Upper Jurassic strata also show a progressive southward advance associated with transgression in that direction. The locus of maximum sandstone deposition for each series shifted southward within the general Waters River area, from near the head of Waters River (western northern Richardson Mountains) in the Middle and possibly Early Jurassic (Poulton et al., 1982), to about Salmon Cache Canyon on Porcupine River in the Late Jurassic.

The sandstones of the basin-marginal belt were localized near their sites of supply to the northern

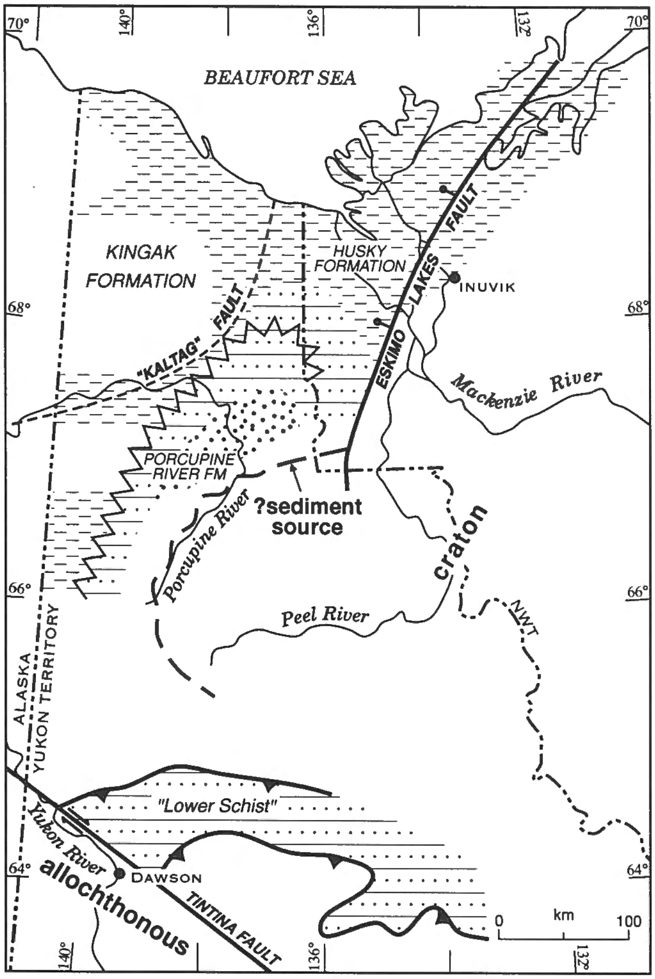


Figure 10.36. *Generalized facies distribution map for Upper Oxfordian to Lower Kimmeridgian strata.*

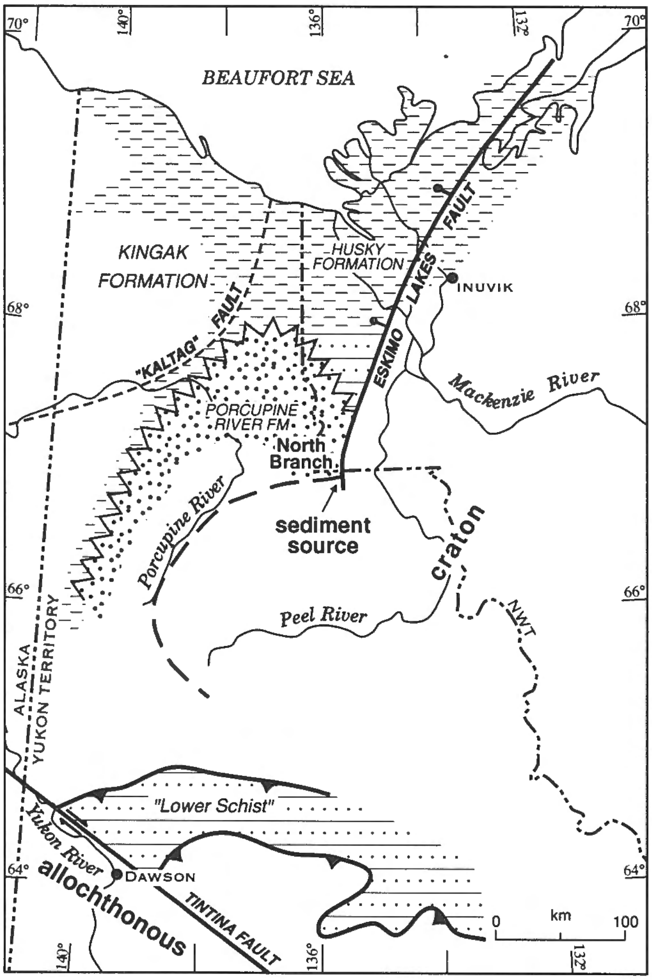


Figure 10.37. *Generalized facies distribution map for Upper Kimmeridgian to Volgian strata.*

Richardson Mountains and adjacent areas by marine redistribution mechanisms and perhaps by minor downwarping. Equivalents of them are absent or reduced along depositional strike to the southwest, in the northern Ogilvie Mountains. In these areas, the younger Husky Formation and equivalent sandstone units appear to have overstepped a thin sequence of older Jurassic rocks, in the same way that they transgressed southeastward over the Bug Creek Group in the northern Richardson Mountains (Poulton, 1982). Jurassic transgression onto a high in northernmost Yukon also appears to be indicated (Norris, 1972, 1973, 1974), although it is not well documented by fossil control. It is not clear whether this was one of a series of unconnected small highs along the unstable cratonic margin, or an extension of Barrow Arch of northern Alaska.

The succession along the southeastern margin of Brooks–Mackenzie Basin records five major regressive events (Fig. 10.38). The Sinemurian and Pliensbachian Murray Ridge and Almstrom Creek formations, the Oxfordian upper Richardson Mountains and Aklavik formations, and the overlying Upper Jurassic Husky, Porcupine River and North Branch formations represent coarsening- and shallowing-upward, progradational shelf successions culminating in significant sandstone deposits. Regressive episodes which resulted in only minor sandstone development are indicated by the shoaling-upward Toarcian and Aalenian Manuel Creek Formation, and the Bathonian and Lower Callovian, lower and middle parts of the Richardson Mountains Formation. The Aalenian or Early Bajocian maximum regression more or less coincided with erosion on the basin margin and development of the White Mountains Uplift and Waters River depocentre on the shelf. The upper beds of the Almstrom Creek Formation, intertongued with Toarcian shales, and the basal sandstone of the Richardson Mountains Formation, which is of Early Bajocian age in the west and Late Bajocian age in the east, are the only significant transgressive deposits. The latter is a lowstand shelf facies in the west and a transgressive facies in the east.

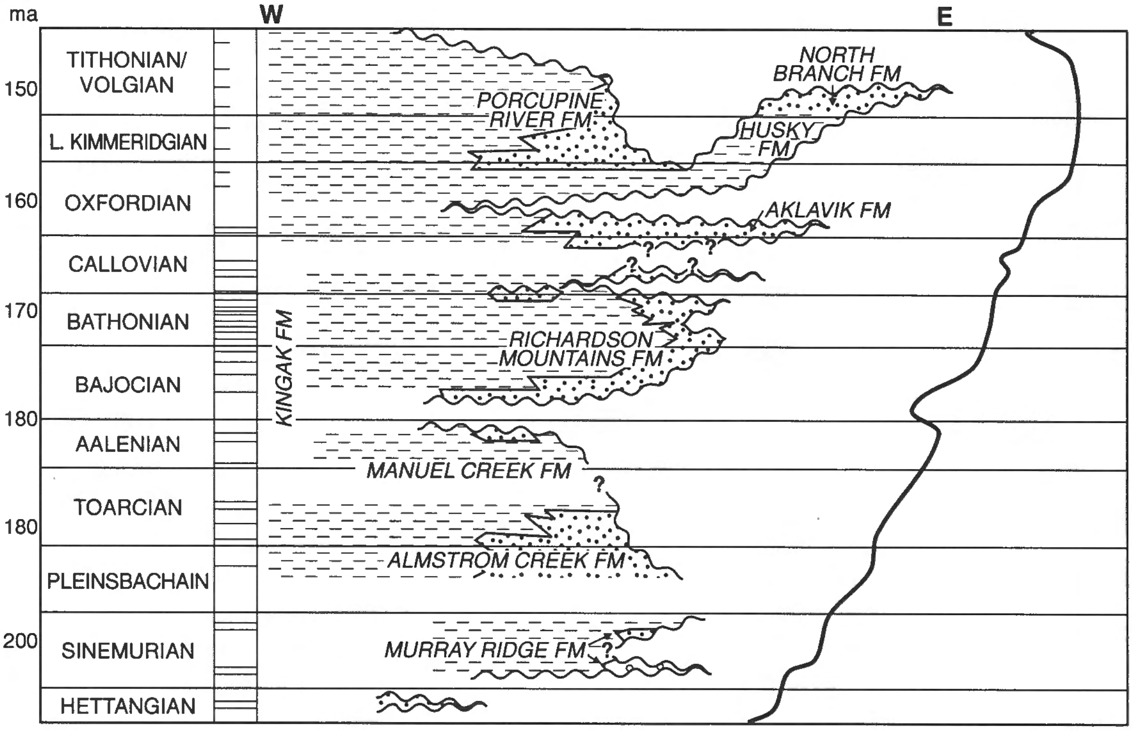


Figure 10.38. *Time-stratigraphic diagram of the Jurassic formations of northern Yukon and adjacent Northwest Territories, and a subsidence versus sedimentation curve (from Poulton, 1988b). The high rate of slope of the curve to the right indicates a high rate of subsidence compared with rate of deposition; the inflections to the left are major regional regressive events. The bars in the column next to the stage names at the left indicate diagnostic ammonite occurrences; shorter bars in the upper part of the same column indicate diagnostic* ***Buchia*** *occurrences.*

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Interbedded fine to coarse clastics of the Upper Cretaceous Cuesta Creek Member? of the basal Tent Island Formation, dipping gently seaward (northeast) along lower Trail River Yukon Coastal Lowland. GSC photo 662-25.

CHAPTER 11

CRETACEOUS AND TERTIARY

J. Dixon

Dixon, J., 1996. Cretaceous and Tertiary. In The Geology, Mineral and Hydrocarbon potential of Northern Yukon Territory and Northwestern District of Mackenzie. Geological Survey of Canada, Bulletin 422, p. 301–317.

Abstract

Cretaceous and Tertiary strata, which are widely exposed throughout the Operation Porcupine map area, consist of alternating shale- and sandstone-dominant formations. Sandstone-rich Lower Cretaceous strata tend to form a northeast-trending belt, extending from the Tuktoyaktuk Peninsula, through the northern Richardson Mountains, and across the northern edge of Eagle Plain, turning southward along the northern Ogilvie Mountains. Northwestward of the sandstone belt, the succession tends to become shalier. The bulk of these Lower Cretaceous rocks are easterly- to southeasterly-derived, shoreline to shelf sediments, dominated by storm deposits. However, in parts of northern Yukon, some Albian strata contain thick successions of westerly-derived sediment gravity-flow deposits formed during a major tectonic event associated with orogeny in the ancestral Brooks Range. Berriasian to Aptian sedimentation was associated with rift tectonics, and during the late Aptian and Albian, the northern Yukon and adjacent Northwest Territories were subjected to both rifting and compression.

A major unconformity separates Lower and Upper Cretaceous strata. Upper Cretaceous and Tertiary strata reflect a different tectono-stratigraphic regime, wherein sediments were derived from the the rising Cordilleran orogen to the south and southwest. Cenomanian to early Maastrichtian sediments were deposited in a cratonic foreland basin, whereas since Late Maastrichtian time, deposition has been on the subsiding continental margin of Canada Basin. Upper Cretaceous and Tertiary strata are dominated by deltaic and delta-front sediments in their onshore and nearshore occurrences, grading into prodelta/shelf, slope and basinal deposits in the offshore areas.

Résumé

Les couches crétacées et tertiaires, qui affleurent abondamment dans la région cartographiée dans le cadre de l'Opération Porcupine, sont composées de formations alternantes renfermant surtout du shale et du grès. Les couches gréseuses du Crétacé inférieur ont tendance à former une zone à direction nord-est, qui, de la péninsule de Tuktoyaktuk, traverse le nord des monts Richardson et la bordure septentrionale de la plaine Eagle, pour tourner ensuite vers le sud en longeant le nord des monts Ogilvie. Vers le nord-ouest de la ceinture de grès, la succession a tendance à devenir plus riche en shale. Ces roches du Crétacé inférieur sont en grande partie des sédiments de littoral à plate-forme continentale provenant de l'est au sud-est et surtout composés de sédiments de tempête. Cependant, dans certaines parties du nord du Yukon, certaines couches albiennes contiennent des successions épaisses de sédiments de coulée par gravité dérivées de l'ouest et formées durant un important épisode tectonique associée à l'orogène dans le chaînon ancestral Brooks. La sédimentation du Berriasien à l'Aptien était associée à une tectonique d'effondrement, et durant l'Aptien tardif et l'Albien, le nord du Yukon et les Territoires du Nord-Ouest adjacents ont subi à la fois une distension et une compression.

Une importante discordance sépare les couches du Crétacé inférieur et supérieur. Les couches du Crétacé supérieur et du Tertiaire reflètent un régime tectonostratigraphique différent, dans lequel les sédiments proviennent de l'orogène de la Cordillère en cours de formation au sud et au

sud-ouest. Les sédiments du Cénomanien au Maastrichtien précoce se sont déposés dans un bassin d'avant-pays cratonique, tandis que depuis le Maastrichtien tardif, la sédimentation a eu lieu sur la marge continentale en subsidence du bassin Canada. Les couches du Crétacé supérieur et du Tertiaire sont surtout composées de sédiments de delta et de front deltaïque dans leur milieu d'accumulation littoral et infralittoral, se transformant en dépôts de prodelta/plate-forme, de talus et de bassin dans les régions extracôtières.

INTRODUCTION

Cretaceous and Tertiary strata outcrop extensively in the Operation Porcupine map area, although Cretaceous strata are far more extensively exposed (Fig. 11.1). Lower Cretaceous rocks are present in the Richardson Mountains, the Blow River drainage basin, northern Eagle Plain, northern Ogilvie Mountains, and the British Mountains. Upper Cretaceous strata are more restricted, but are present extensively on Eagle Plain and as scattered outcrops along Porcupine River in Old Crow Basin, along the Arctic Coastal Plain, and as isolated outcrops on the east flank of Richardson Mountains. Tertiary strata are even more restricted in their outcrop occurrence, being present mostly along the Arctic Coastal Plain and as isolated outcrops on the perimeter of Old Crow Basin and in Bonnet Plume Basin. However, there is a thick accumulation of Tertiary strata under Mackenzie Delta and the Beaufort Sea shelf.

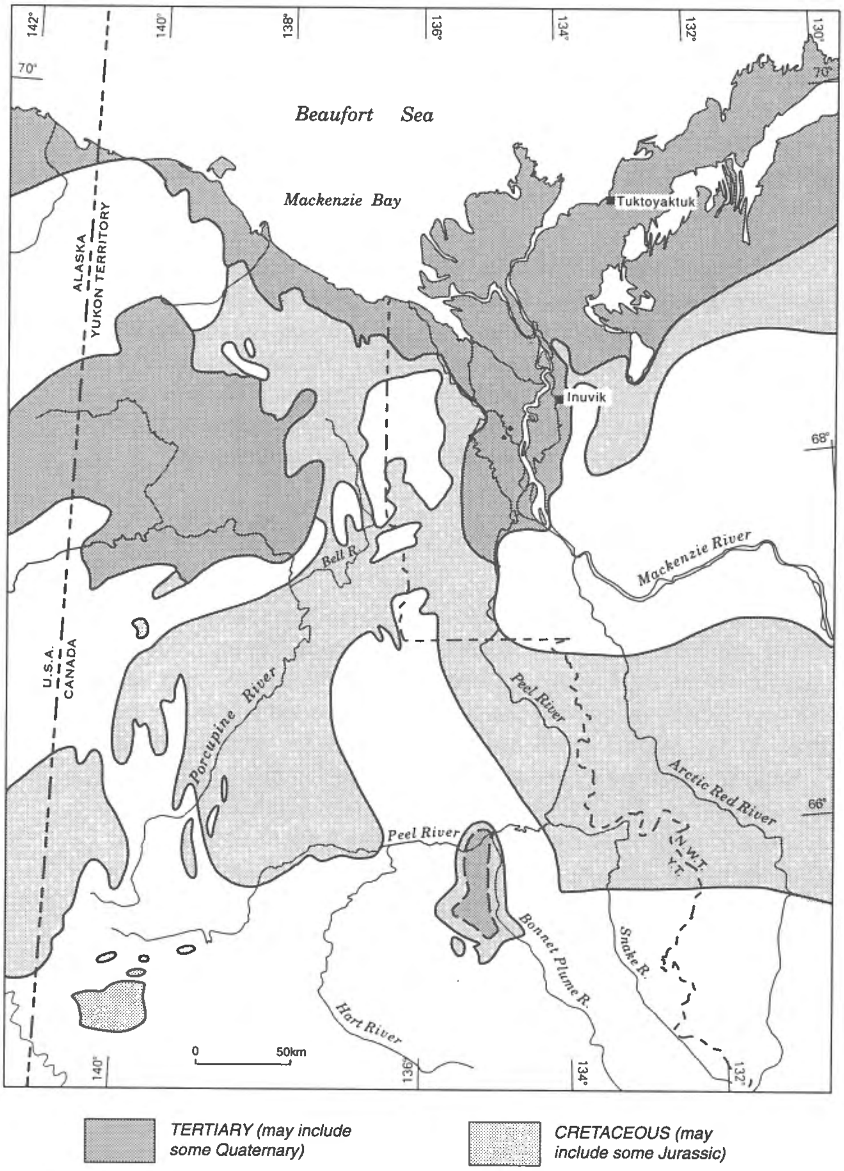

__Figure 11.1.__ Location map and distribution of Cretaceous and Tertiary strata (after Norris, 1981a–l; 1982a–d, 1985).

PREVIOUS WORK

Early studies of Cretaceous and Tertiary strata began in earnest with the initiation of Operation Porcupine by the Geological Survey of Canada and also by petroleum exploration companies. Much of the early published work was by Jeletzky (1958, 1960, 1961, 1964, 1967, 1971a, b, 1972, 1973, 1974, 1975a, b, 1980), who concentrated on Jurassic and Lower Cretaceous stratigraphy and biostratigraphy. Maps showing the distribution of Cretaceous–Tertiary strata include those of Norris et al. (1963) and Norris (1981a–l, 1982a–d, 1985). Preliminary studies of Upper Cretaceous and Tertiary stratigraphy were briefly outlined by Mountjoy (1967). Mountjoy and Chamney (1969) studied Albian sediments and foraminifers in and around the Trevor Range.

More recent studies have included the work of Young (1971, 1972, 1973a, b, 1975a, b, 1977), Young et al. (1976), and Young and Robertson (1984), who concentrated their efforts mostly in the northern part of Operation Porcupine area. Coté et al. (1975), Dixon (1979, 1982a, b), and Dixon et al. (1985, 1989) presented studies of the subsurface occurrence of Cretaceous and Tertiary strata. More localized studies have included the work of Norris and Hopkins (1977), and Long (1981) on the Bonnet Plume Basin; Ricketts (1988) on the Upper Cretaceous Monster Formation; and Dixon (1986a, 1988, 1992a) on the Albian Sharp Mountain Formation, the Maastrichtian Cuesta Creek Member and the Upper Cretaceous of Eagle Plain. Work on Tertiary stratigraphy and sedimentology can be found in Holmes and Oliver (1973), Hawkings and Hatlelid (1975), Young (1975a), Young et al. (1976), Price et al. (1980), Nentwich and Yole (1982), Willumsen and Cote (1982), Young and McNeil (1984), Dietrich et al. (1985, 1989), Dixon (1981) and Dixon et al. (1985).

Regional syntheses have been written by Lerand (1973), Miall (1973), Norris (1974), Young et al. (1976), Balkwill et al. (1983), and Dixon (1986b, 1992b).

OBJECTIVES

This chapter is a brief overview of Cretaceous and Tertiary stratigraphy and sedimentology of the land areas of the Operation Porcupine map area. The geology of the offshore areas is dealt with in Chapter 12. Cretaceous–Tertiary history is presented in terms of tectonic phases of development (Young, 1973a; Dixon, in press); each phase is characterized by a dominant style of tectonism, a characteristic type of sedimentation and a general commonality of paleogeographic conditions. The correlations presented in Figure 11.2 are the stratigraphic basis for developing the history. Three phases of tectonism are recognized: a rifting phase that began in the Jurassic, or possibly earlier; a late Aptian to Albian phase of rifting and compression; and a compressional phase that began in the Cenomanian.

RIFTING PHASE

From the Early Jurassic, and possibly even earlier, up to the mid-Aptian, rifting was the dominant tectonic activity in the northern Yukon and adjacent Northwest Territories. Rifting was associated with extension in the North American craton which would eventually lead to the formation of oceanic crust in the Canada Basin. During this phase of tectonic activity, fault-bounded uplifts and depressions characterized the northern Yukon and adjacent Northwest Territories (Fig. 11.3). Features such as the Eskimo Lakes Arch, Cache Creek Uplift, Eagle Arch and a northern part of the Romanzof Uplift were prominent positive elements on which Berriasian to mid-Aptian sediments may be thin or eroded. Kugmallit Trough, Canoe Depression, Vittrekwa Embayment, Rapid Depression (Blow Trough), Keele Trough and Kandik Basin/Trough were major depocentres.

Sedimentation during the rift phase was characterized by an eastern to southeastern provenance (Dixon, 1986b) from which mature clastics, deposited as quartz arenites and shales, were derived. During the Berriasian to early or middle Hauterivian, the facies belts trended southwest, from Tuktoyaktuk Peninsula, through the northern Richardson Mountains, along the northern edge of Eagle Plain and then turned southward along the northern Ogilvie Mountains. Along this trend there is an inner sandstone-rich facies belt, northwestward and westward of which the succession is shale-dominant. These trends are well illustrated by upper Berriasian strata (Fig. 11.4), wherein the sandstone-dominant belt is represented by strata of the Martin Creek Formation and those of the shale-dominant facies belt by the Kingak Formation. From the Mackenzie Delta area westward to the British Mountains, the facies changes are well represented in the outcrop belts. Under Mackenzie Delta and the nearby eastern flank of Richardson Mountains, the Martin Creek Formation is almost entirely sandstone and has been interpreted as shoreface sediment (Fig. 11.5A; Jeletzky, 1958; Myhr and Young, 1975; Young, 1978; Dixon, 1982a, b). On the west flank of the Richardson Mountains, Martin Creek strata contain much more interbedded shale and consist of

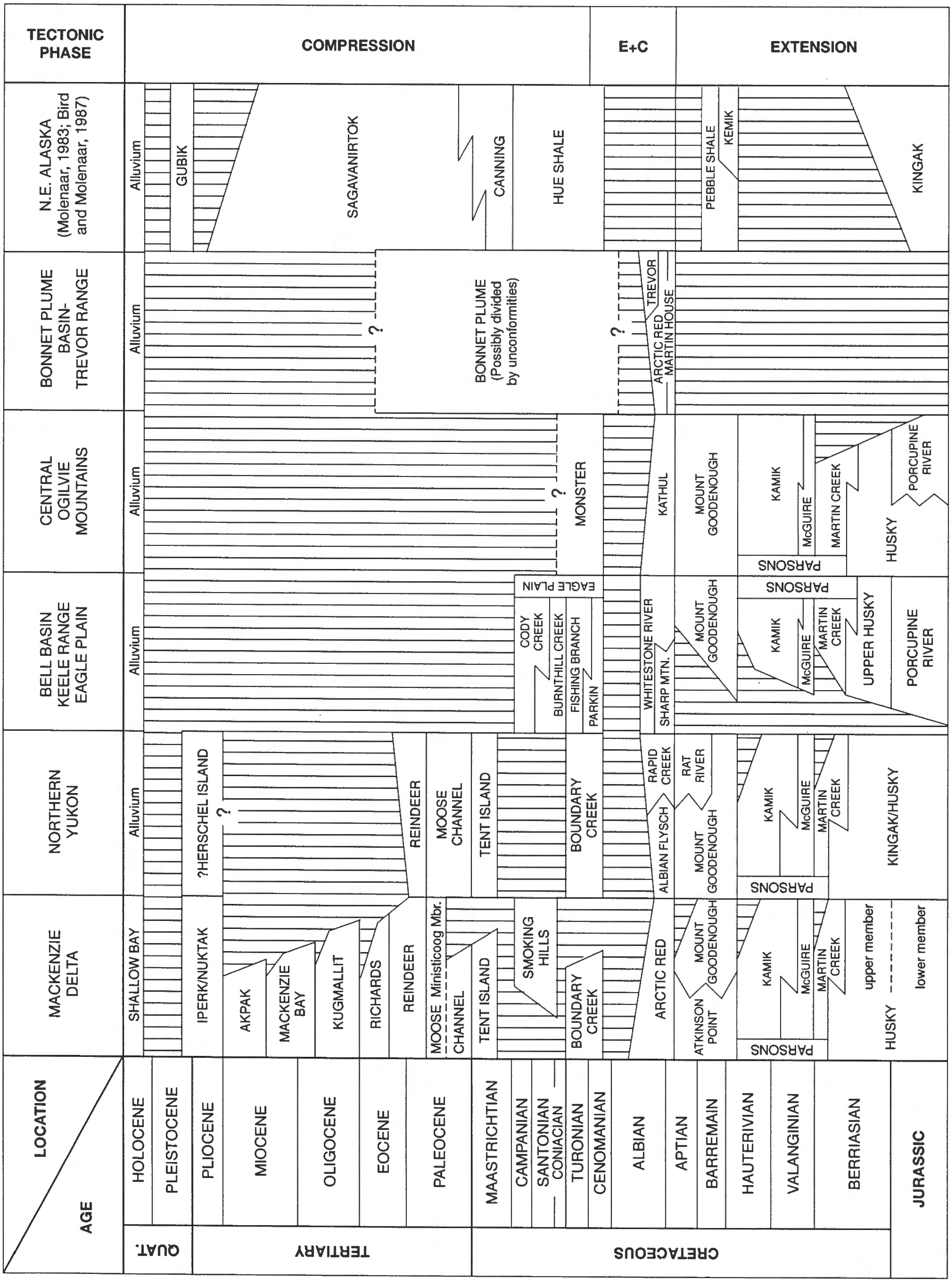

Figure 11.2. Table of formations.

several coarsening-upward cycles (Fig. 11.5B). The sandstones in the cycles may be bioturbated, subhorizontally laminated or hummocky cross-stratified. These sedimentological features suggest deposition below normal wave-base, in a storm-dominant environment on the inner shelf to lower shoreface. Farther westward, in the British Mountains, upper Berriasian strata in the Kingak Formation are mostly shale with thin interbeds of generally bioturbated, silty to argillaceous sandstone. These western occurrences of upper Berriasian strata are interpreted as shelf sediments, deposited below storm wave-base. The change from sandstone-rich to shale-rich Berriasian strata tends to occur across the Rapid Depression.

During the Valanginian and early to middle Hauterivian, there was a major influx of coarse clastic sediments, resulting in the deposition of the Kamik Formation (Fig. 11.6). Although the paleogeographic conditions remained essentially similar to those of the Berriasian, the extent of the sandstone belt was greatly expanded, extending across the Rapid Depression into the area of the southeastern Romanzof Mountains (Fig. 11.7). Also during the late Valanginian, and possibly the early Hauterivian, a delta formed in the vicinity of the modern Tuktoyaktuk Peninsula and south Mackenzie Delta (Dixon, 1982a, b; Fig. 11.7). This delta was probably the main source of the large volume of coarse clastic sediments on the shelf areas.

The end of Kamik sedimentation is marked by a major regional unconformity and transgression. Subsequently there appears to have been an expansion of the depositional basin, especially in the Eagle Plain

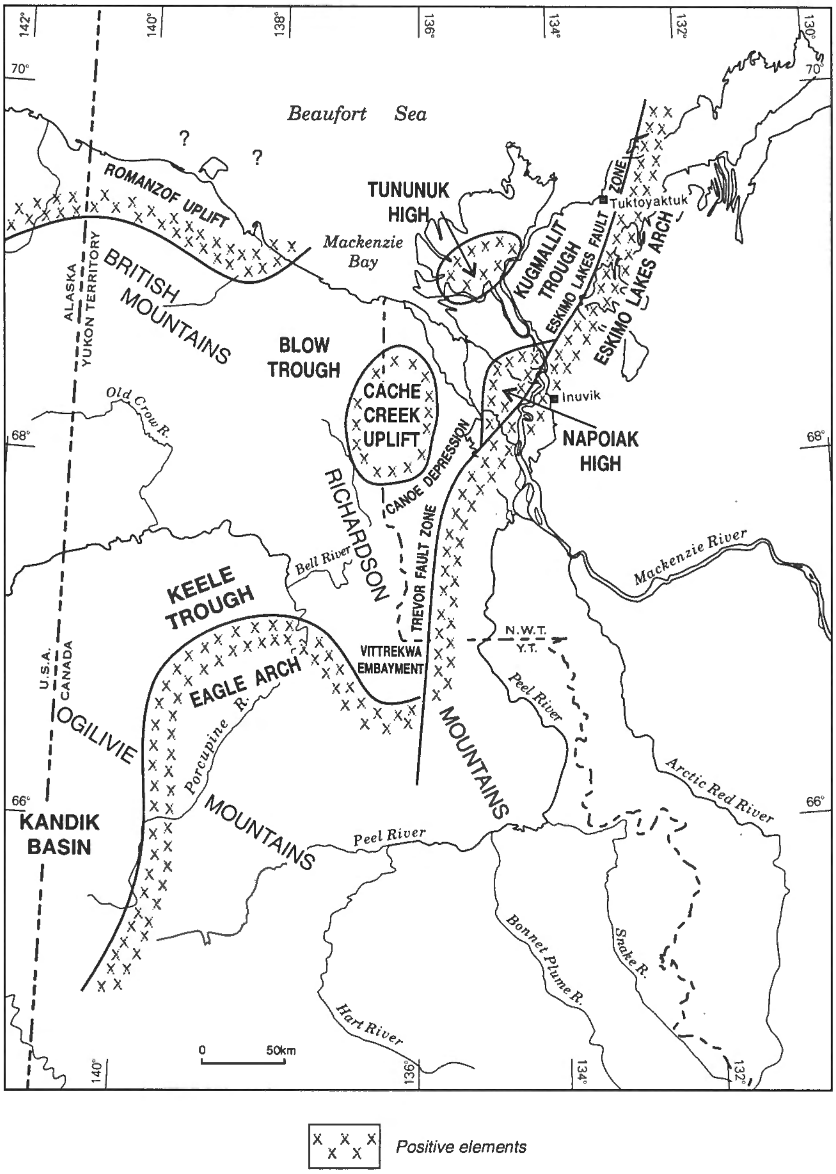

Figure 11.3. *Neocomian tectonic elements. Not all the elements were positive throughout the entire Neocomian; for example, the Romanzof and Cache Creek uplifts can only be identified as positive elements during the Hauterivian.*

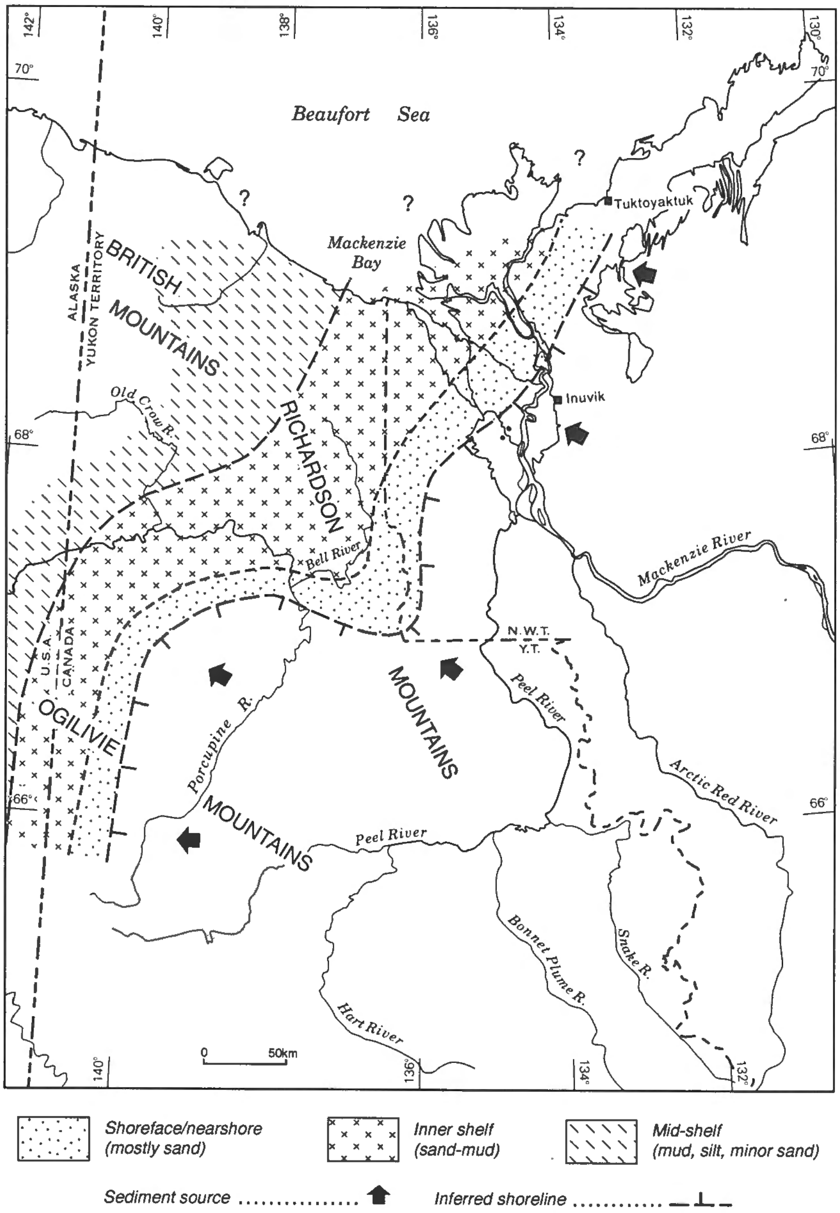

Figure 11.4. Interpreted distribution of late Berriasian depositional facies: Martin Creek Formation and equivalent strata.

area on Peel River, where an outlier of Barremian shales (Norris, 1982b) rests unconformably on Permian strata (Fig. 11.8). Late Hauterivian to Barremian sediments are represented by the shale-dominant Mount Goodenough Formation, which grades up and passes laterally into the sandier Rat River Formation locally and the Atkinson Point Formation under Tuktoyaktuk Peninsula (Dixon, 1979; Dixon et al., 1989). Where Rat River strata overlie Mount Goodenough beds, they are late Barremian to Aptian in age, although the equivalent strata may extend into the early Barremian at the basin margins, under Tuktoyaktuk Peninsula and on the plateau flanking the eastern side of the central Richardson Mountains. Locally developed basal transgressive sandstones are present on the east flank of the Richardson Mountains, and on the northeastern flank of the Romanzof Mountains and adjacent coastal plain (e.g., in the Roland Bay L-41 and Spring River N-58 wells). These basal sandstones tend to be better developed on and adjacent to Early Cretaceous tectonic highs (Fig. 11.3), where the basal unconformity has cut deeply into underlying strata. This is readily seen on the east flank of Cache Creek Uplift, where well exposed strata in "Grizzly Gorge" (informal geographic name) show a truncated Kamik Formation overlain by Mount Goodenough strata (Fig. 11.6). The northerly truncation of pre-Mount Goodenough strata on the northeast flank of the Romanzof Uplift may reflect the presence of a northern uplifted area similar to the Alaskan Barrow Arch (Bird, 1985). A similar stratigraphy is seen in adjacent northeast Alaska,

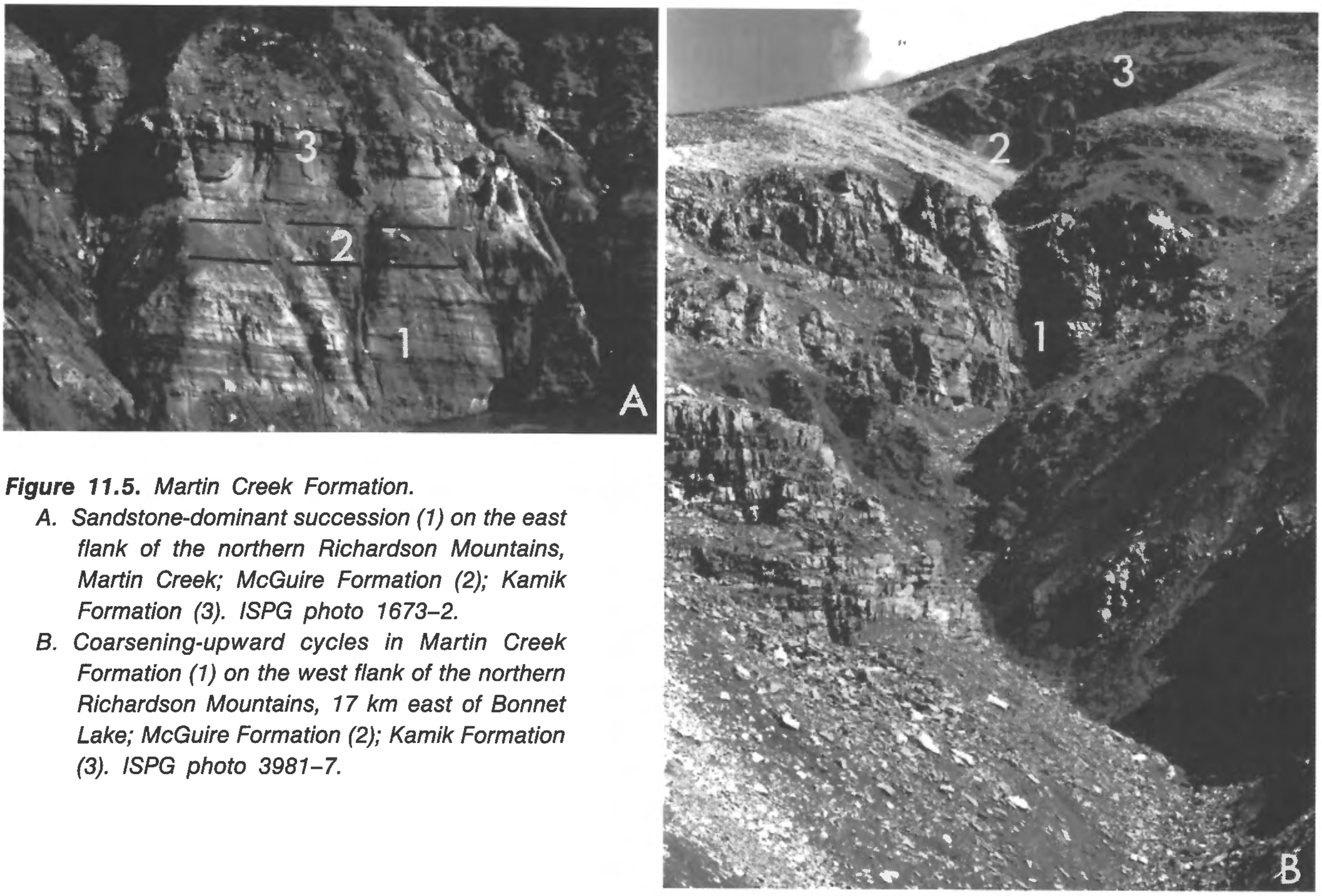

Figure 11.5. *Martin Creek Formation.*

A. Sandstone-dominant succession (1) on the east flank of the northern Richardson Mountains, Martin Creek; McGuire Formation (2); Kamik Formation (3). ISPG photo 1673–2.

B. Coarsening-upward cycles in Martin Creek Formation (1) on the west flank of the northern Richardson Mountains, 17 km east of Bonnet Lake; McGuire Formation (2); Kamik Formation (3). ISPG photo 3981–7.

where the Kamik sandstone and overlying Pebble Shale erosionally overlie older strata (Mull, 1987).

Barremian to early Aptian paleogeography is marked by a broad shelf area on which muds were the dominant sediments, with a shoreline facies developed under Tuktoyaktuk Peninsula and east of the Richardson Mountains (Fig. 11.9). A local fan delta formed on Tuktoyaktuk Peninsula (Dixon, 1979; Fig. 11.7), associated with the Eskimo Lakes Fault Zone. Progradation of inner shelf, storm-deposited, coarse clastic sediments (Rat River Formation) extended as far as the eastern edge of Rapid Depresssion.

RIFTING AND COMPRESSIONAL PHASE

In the late Aptian/early Albian there was a major transgression and substantial expansion of the depositional area. The transgressive beds are represented by strata of the Martin House Formation (Mountjoy and Chamney, 1969) and local coarse clastic rocks at the base of the Arctic Red Formation. These transgressive beds overlap Rat River strata southward on Peel Plateau, to rest directly on Upper Devonian beds (Fig. 11.10). A similar relationship is noted under Tuktoyaktuk Peninsula, where Albian Arctic Red strata overlap Atkinson Point strata on the

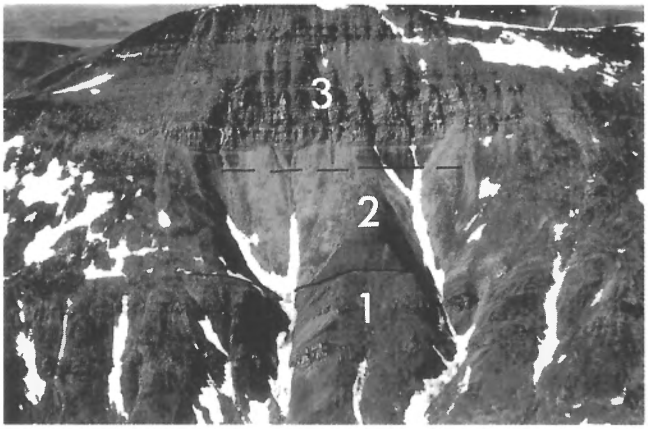

Figure 11.6. *Martin Creek (1), McGuire (2) and Kamik (3) formations on the west flank of the northern Richardson Mountains, approximately 5 km north of Mount McGuire. ISPG photo 1858–3.*

Eskimo Lakes Arch and rest on mostly Upper Devonian strata. In parts of northern Yukon, the Albian transgression appears to have been preceded by local uplift and erosion; for example, on the northwest flank of Cache Creek Uplift (Young, 1977), the east flank of Barn Uplift (Young, 1974), and along the northern edge of Eagle Plain (Dixon, 1992b). These erosional events were probably related to a combination of rifting along the proto-Arctic margin and crustal shortening at the east end of the Alaskan orogen.

A change in the provenance of the clastic sediments accompanied the transgression. During the rifting phase, sediment was derived principally from cratonic areas to the east and southeast of the paleoshoreline, whereas in the Albian, sediment sources were from the south and west, where the Cordilleran Orogen was being compressionally deformed. However, thick accumulations of Albian sediment were being deposited in basins that are interpreted as originating as rift grabens and half-grabens; these include Kugmallit Trough, Blow Trough (Rapid Depression), Keele Trough, and Kandik Trough. Sediment gravity-flow deposits were deposited within these tectonic and bathymetric depressions (Figs.11.11, 11.12). In Blow, Keele and Kandik troughs, such deposits have thick intervals of conglomerate and sandstone (Albian Flysch of Young, 1977; Sharp Mountain Formation of Dixon, 1986a; and Kathul Formation respectively) derived from the ancestral Brooks Range (Brooks Range Geanticline of Young

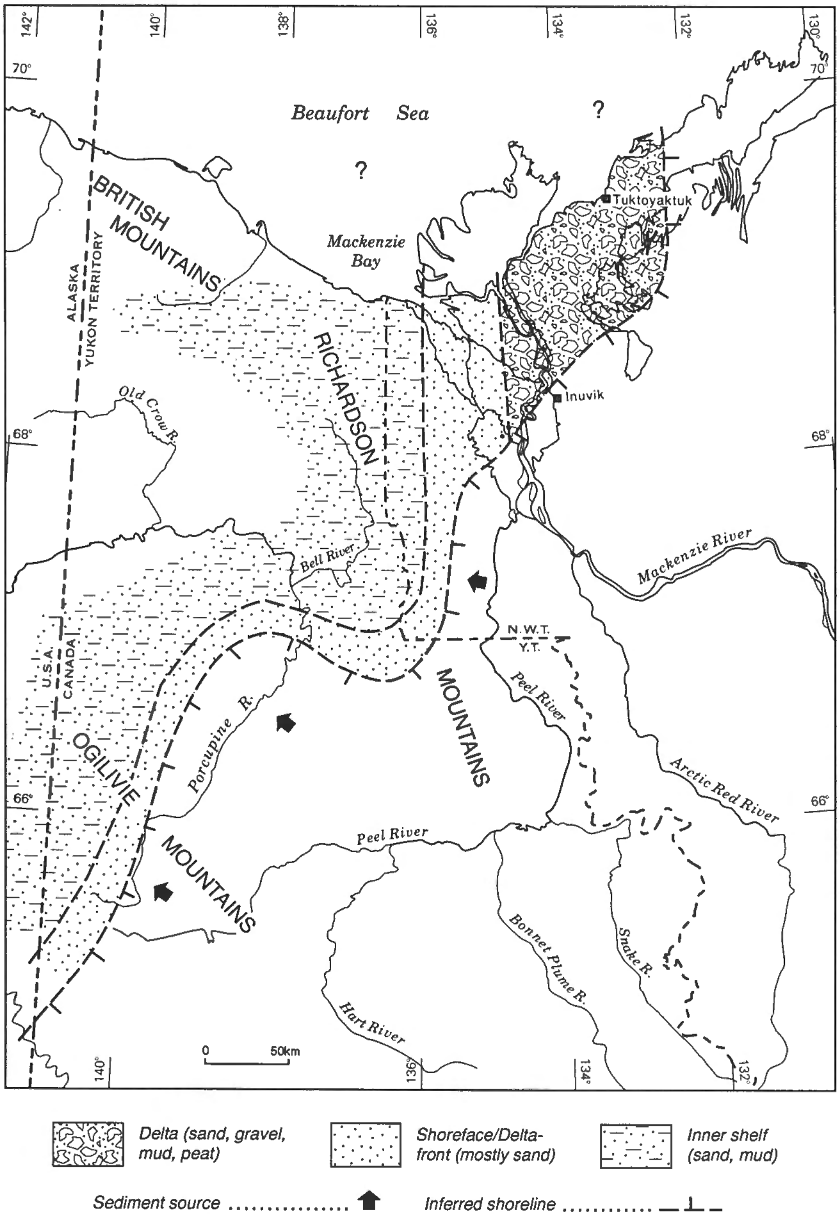

Figure 11.7. *Interpreted distribution of late Valanginian to early Hauterivian depositional facies: lower Kamik Formation.*

et al., 1976). In the Kugmallit Trough, similar deposits are shale-dominant because of the distal position of the trough relative to its source terrane (Dixon et al., 1989; Fig. 11.9).

South and southeast of the troughs are areas of shelf sediments, the preserved record of which is represented mostly by shales of the Arctic Red and Whitestone River formations. Adjacent to the modern Mackenzie Mountains are the preserved remnants of inner shelf to shoreline sands (Trevor Formation) of a shallow foreland basin (Peel Trough of Yorath and Cook, 1981) that began to form in the Albian and continued into the Late Cretaceous.

The Kugmallit Trough offers the best evidence of a rift origin for the major Albian troughs. Here the strata have not been overprinted by Tertiary deformation, and seismic reflection data show the relationship between structure and stratigraphy (Cook et al., 1987a, b). Normal faults of the Eskimo Lakes Fault Zone extend through Jurassic and Lower Cretaceous strata, some continuing into Upper Cretaceous and Tertiary rocks. However, the greatest offset is in pre-Upper Cretaceous rocks and the geometry of the strata clearly show a down-to-the-northwest displacement and rotation on the fault planes. Furthermore, reflection seismic surveys across the Kugmallit Trough show that Albian strata (Arctic Red Formation) contain northward prograding slope clinoforms downlapping basinal strata (Dixon et al., 1989). The lithotypes and contained fauna and flora tend to confirm the interpretation of the strata as outer shelf and slope facies. Rapid thickness increases across the fault zone are typical of the Albian succession, although mid-Cretaceous and Tertiary erosion can account for some of the thinning on the Eskimo Lakes Arch.

In northern Yukon, the changes in thickness of Albian strata between the Cache Creek Uplift and adjacent Blow Trough are very pronounced, changing from a few hundred metres to over 4000 m (Young, 1977). Under Eagle Plain, the northward thickness increase from shelf to deeper water sediments is more gradual than that seen in the Kugmallit and Blow troughs (Dixon, 1992b), although there is a slightly more rapid thickening of Albian strata where deeper water sediments are interpreted to become more prevalent.

An unusual Albian facies is present on the eastern flank of Blow Trough, extending on to the northwest flank of Cache Creek Uplift; these are the iron

Figure 11.8. *"Grizzly Gorge", northeast Richardson Mountains: Mount Goodenough strata (4) erosionally overlying truncated Kamik strata (3), in turn overlying the McGuire (2) and Martin Creek (1) formations. ISPG photo 2057–4.*

phosphate-rich beds of Rapid Creek Formation (Young and Robertson, 1984). Young and Robertson (op. cit.) concluded that the phosphates probably formed from cold, upwelling currents along the western edge of Cache Creek Uplift.

Most of the preserved Albian succession is only as young as Middle Albian, although possible Late Albian strata may be locally preserved in Bonnet Plume Basin (A. Sweet, pers. comm., 1987) and possibly as part of the Trevor Formation. In Bonnet Plume Basin, the possible Late Albian rocks are nonmarine conglomerates and coarse sandstones; those of the Trevor Formation are marine, nearshore sediments.

COMPRESSIONAL PHASE

A major regional unconformity to disconformity separates Upper Cretaceous from Lower Cretaceous and pre-Cretaceous strata throughout most of the study area (Fig. 11.13). The unconformity marks a dramatic change from the deep-water troughs, broad mud-rich shelf areas, and poorly defined foreland basins during the Albian, to the post-Albian development of better defined foreland basins infilled with considerable quantities of coarse clastic sediment derived from the Cordilleran Orogen. The Albian deep-water troughs were filled and the locus of deeper water sedimentation shifted northward. Also, the

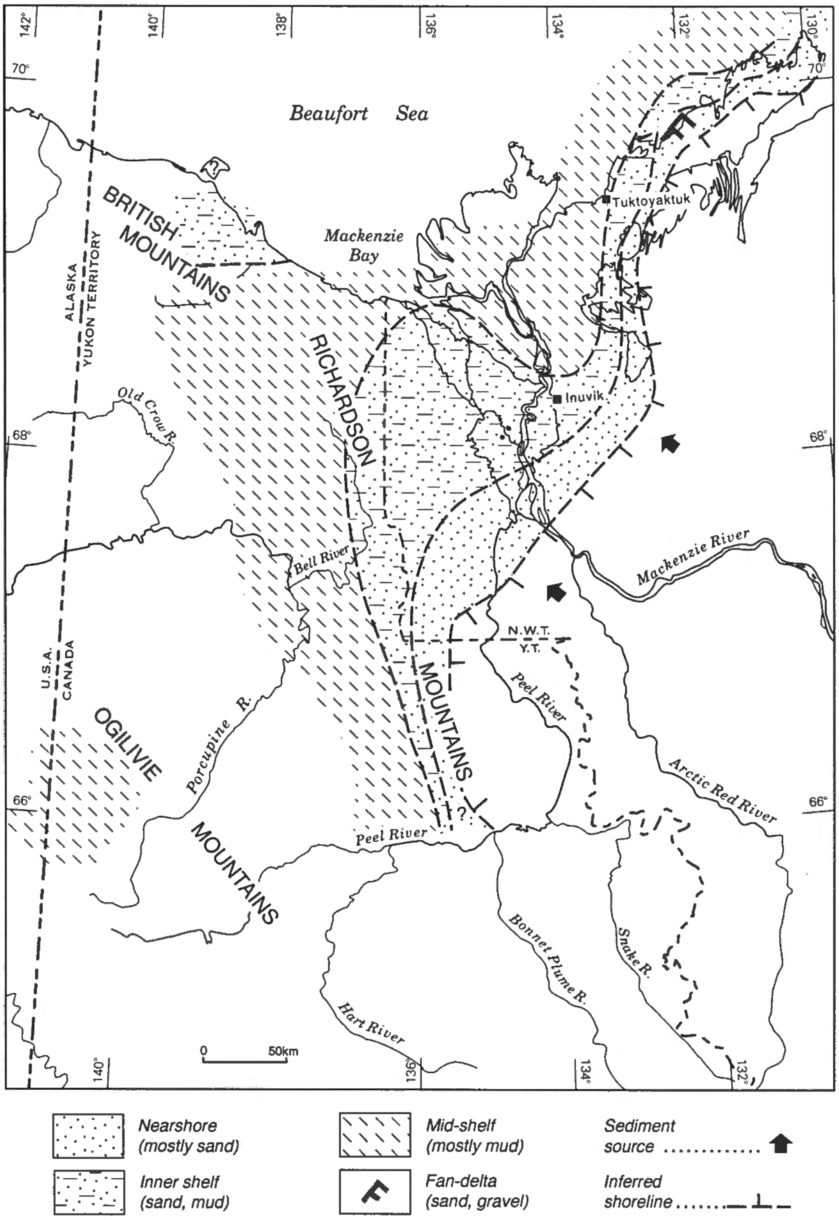

Figure 11.9. *Interpreted distribution of Barremian/Early Aptian depositional facies: Mount Goodenough, Rat River, and Atkinson Point formations.*

mid-Cretaceous unconformity has been interpreted as the breakup unconformity (Dixon, in press; Embry and Dixon, 1990), separating strata formed during rifting from strata deposited during the drift separation of the continental margins of Canada Basin. There is not any known evidence of an unconformity in the Albian to Upper Cretaceous Trevor Formation.

During the Cenomanian to Holocene, two distinct phases of sedimentation can be recognized. The early phase, characterized by deposition on the continental area, lasted until the middle or late Maastrichtian; the late phase, characterized by sedimentation on the continental margin of Canada Basin, is still active. During the early phase, a broad belt of nonmarine to inner shelf, coarse clastic-dominant sediments was deposited in a shallow foreland basin north of the early formed part of the Cordilleran Orogen (Fig. 11.14). These strata consist of the Monster Formation (Ricketts, 1988), Eagle Plain Group (Dixon, 1992b), Trevor Formation (Yorath and Cook, 1981), and Bonnet Plume Formation (Norris and Hopkins, 1977; Long, 1981). They become progessively shalier northward. In the northern Yukon coastal plain and northernmost Northwest Territories, equivalent strata consist of organic-rich, outer shelf to basinal shales of the Boundary Creek and Smoking Hills formations (Young, 1975a; Yorath and Cook, 1981; Fig. 11.10). Within these Cenomanian to middle Maastrichtian sediments, there are at least two major transgressive–regressive cycles separated by an unconformity or disconformity (Dixon, 1992b). The oldest is Cenomanian to Turonian in age, and the youngest is Santonian to Campanian (possibly as young as Maastrichtian).

In the Maastrichtian, there was a major shift in the locus of sedimentation from the cratonic areas to the continental margin of the Canada Basin. This shift is marked by an unconformity at the base of the Tent Island Formation, and the accumulation of latest Cretaceous to Quaternary sediments, possibly in the order of 10 to 12 km under the outer Mackenzie Delta (Cook et al., 1987a, b), and possiby as much as 16 km thick under the outer shelf areas of the Beaufort Sea. Large delta complexes formed during this phase of sedimentation. At the basin margins, the Tertiary succession consists of alternating shale- and sandstone-dominant intervals that have been given formational names (Young, 1975a; Young and McNeil, 1984; Fig. 11.2). However, these formational rankings become difficult to apply in a more basinward setting and seismic stratigraphic work has recognized the presence of a number of basin-wide transgressive–regressive sequences (Dietrich et al., 1985; Dixon et al., 1985, 1992; Dietrich et al., 1989; Chapter 12).

The earliest Tertiary delta (Moose Channel Formation/Fish River Sequence) was centred over the western Beaufort shelf, and subsequent deltas tended to migrate eastward to slightly east-northeastward until the Miocene. Miocene deltas have not been recognized, although the thickest known successions tend to be under the western Beaufort Sea, where the strata are mudstone-dominant. During the Pliocene and early Pleistocene, the depocentre switched back to the eastern Beaufort Sea, where 3 to 4 km of Pliocene to early Pleistocene strata are present.

In the continental areas, Tertiary strata were deposited in interior basins, where mostly nonmarine

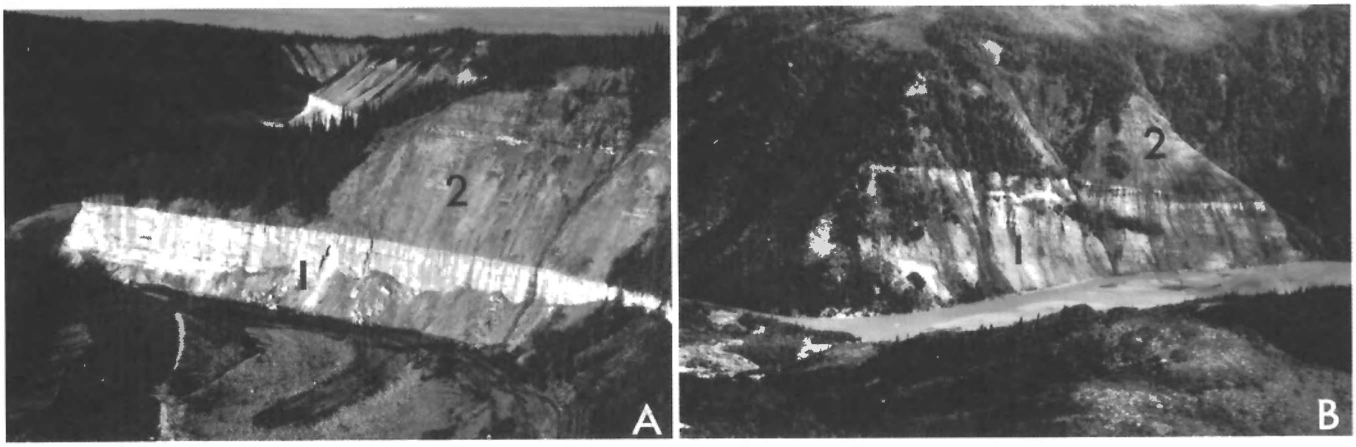

Figure 11.10. *Upper Aptian/lowermost Albian transgressive beds in the western part of Peel Plateau, adjacent to the Richardson Mountains.*

A. Stony Creek: Martin House Formation (2) resting abruptly on Rat River strata (1). ISPG photo 3081–9.

B. Vittrekwa River: Martin House Formation (2) resting unconformably on Upper Devonian beds (1). ISPG photo 1358–25. Locality B is about 29 km south-southwest of locality A.

beds are present (e.g., Bonnet Plume and Old Crow basins). The bulk of the preserved Tertiary in the continental interior consists of Lower Tertiary strata.

Tertiary compressional deformation is evident from the structures visible in outcrop and in Tertiary strata under the Beaufort shelf. Outcrop strata have been thrust faulted and folded (Norris, 1981a–l; 1982a–d; Lane, 1988). In the offshore Tertiary succession, the strata have been deformed into a broad arcuate array of folds (Dixon et al., 1985, figs. 44, 47; Chapter 12), the innermost of which commonly have north-directed contraction faults, generally on their northern flanks. Maximum deformation appears to have culminated in the middle Eocene, with continuing, but lesser, deformation into the late Miocene. In the central and eastern Beaufort Sea areas, younger listric growth faults crosscut the older folds. Since the late Miocene, there has been minimal deformation, although in northeastern Alaska, strong deformation continued during the Pliocene and Holocene.

The combination of a thermally subsiding continental margin and tectonic loading of a northward migrating foredeep created the requisite conditions for the accumulation of a thick and strongly deformed, Upper Cretaceous to Tertiary succession. These conditions have produced a sedimentary basin with considerable economic potential for hydrocarbons (Dixon et al., 1988).

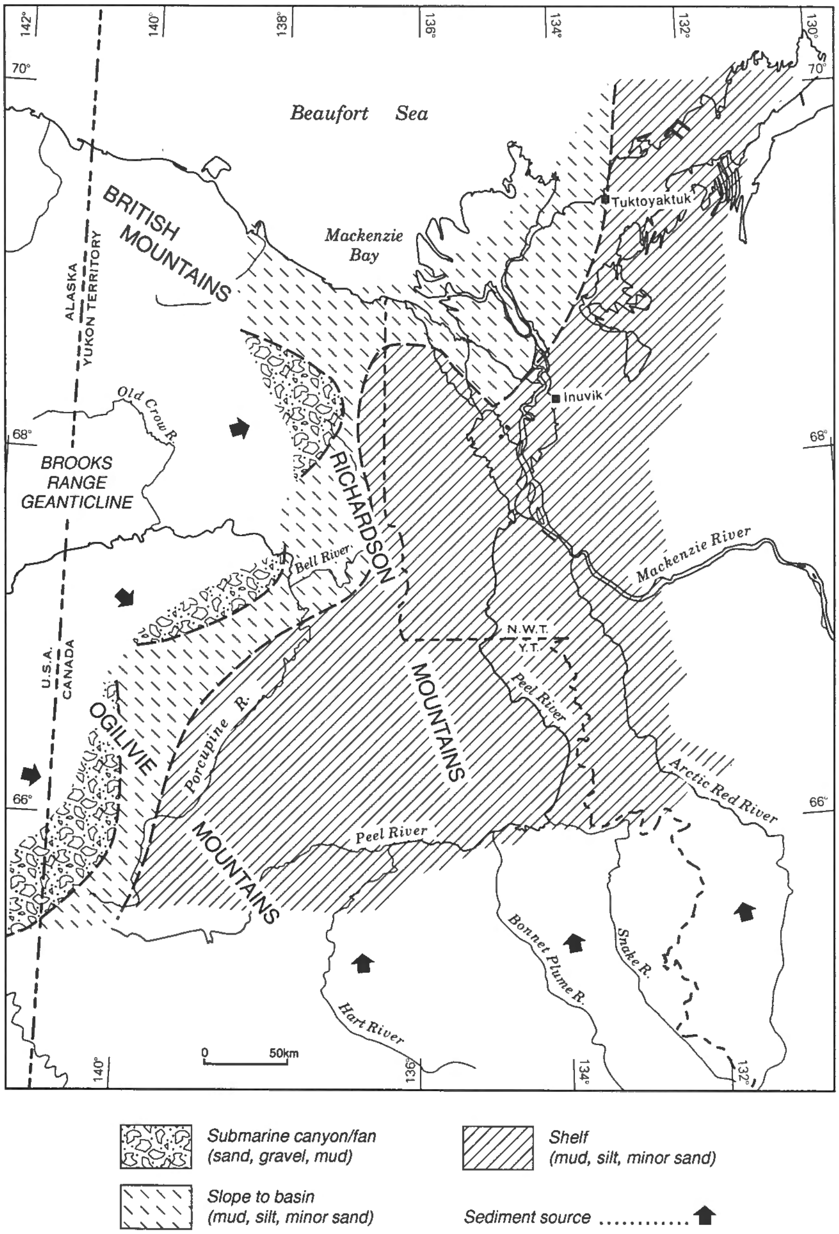

Figure 11.11. *Interpreted distribution of Early Albian depositional facies: Albian Flysch, Arctic Red Formation, Whitestone River Formation, Sharp Mountain Formation, and Kathul Formation.*

Figure 11.12. *Albian sediment gravity-flow deposits.*
A. Albian flysch (Blow Trough), Anker Creek. ISPG photo 3081–4.
B. Kathul Formation (Kandik Basin), tributary of Kandik River. ISPG photo 2619–3.

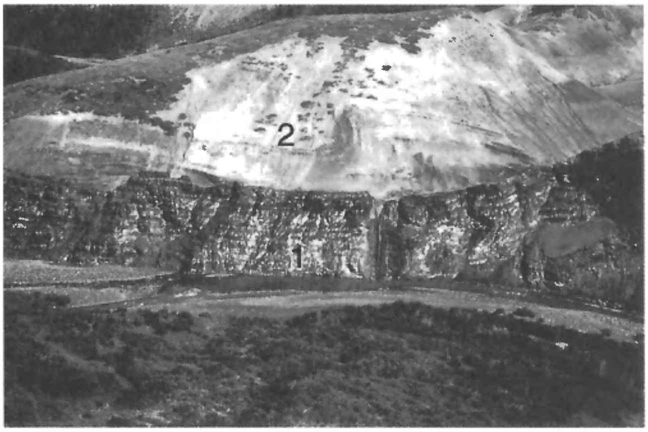

Figure 11.13. *Fish River, northern Richardson Mountains: disconformity between Cenomanian Boundary Creek Formation (2) and Early to Middle Albian flysch (1). ISPG photo 2236–7.*

SUMMARY AND CONCLUSIONS

Cretaceous to Tertiary strata can be divided into three tectono-stratigraphic assemblages, each deposited during a phase characterized by a dominant type of tectonism and common paleogeographic conditions. Up to the late Aptian, rifting was prevalent, and easterly to southeasterly derived sediments were deposited on a broad cratonic shelf. In the late Aptian there was a major transgression and many of the the pre-late Aptian grabens became the sites of major bathymetric and tectonic troughs in the northern Yukon and Mackenzie Delta areas. These troughs appear to have been formed during a major phase of extension but their Albian sedimentary fill was derived principally from the compressional Cordilleran Orogen to the west and south. Since the Cenomanian, the Cordilleran Orogen has been the sediment source, and its northward migration produced a northward migrating foreland basin. In the late Maastrichtian, sedimentation shifted onto the subsiding continental margin of the Canada Basin, resulting in the accumulation of 12 to 16 km of Upper Cretaceous and Tertiary strata with considerable proven and potential hydrocarbon accumulations.

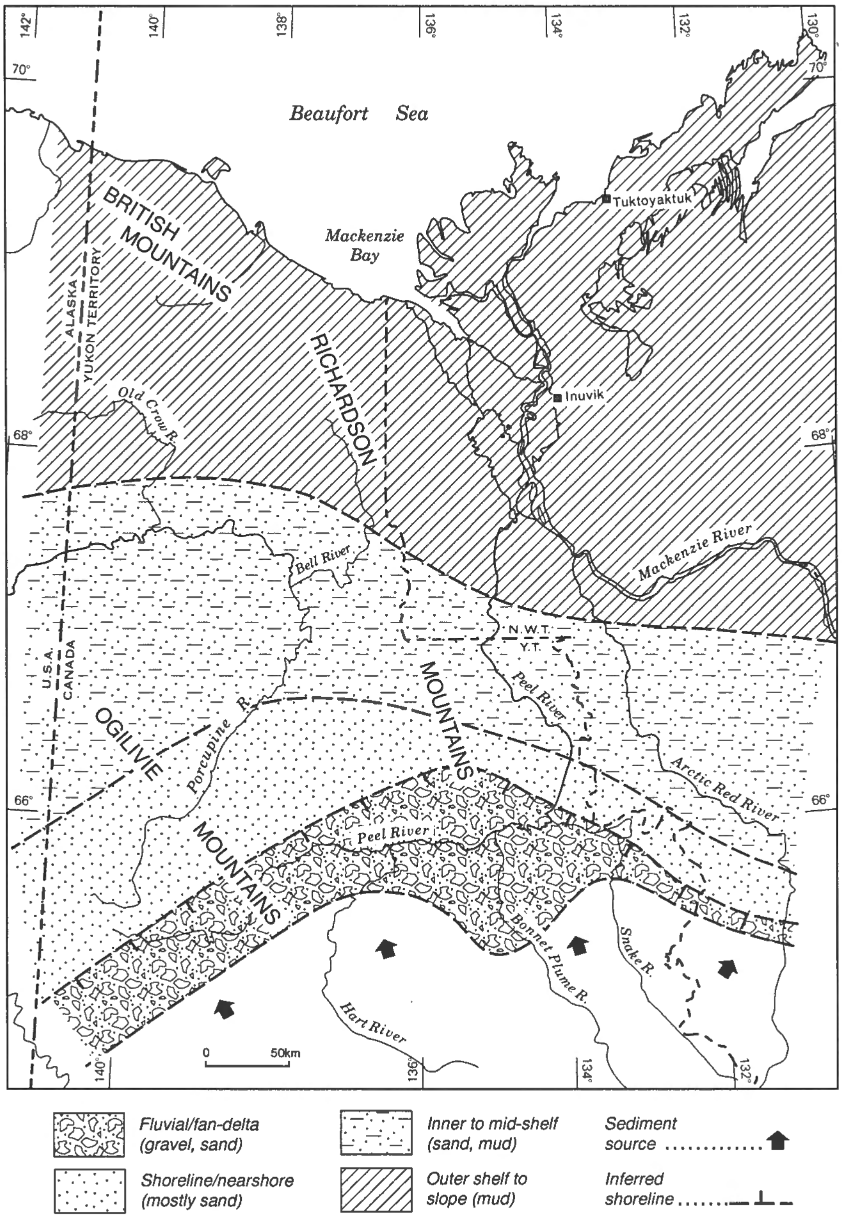

Figure 11.14. Interpeted distribution of Late Cretaceous depositional facies: Monster Formation, Eagle Plain Group, Bonnet Plume Formation, Trevor Formation, Boundary Creek Formation, and Smoking Hills Formation.

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Acutely folded, coal-bearing Lower Cretaceous Kamik Formation at the headwaters of Bell River, Y.T. GSC photo 662-36.

CHAPTER 12

GEOLOGY OF THE BEAUFORT SEA CONTINENTAL SHELF

J.R. Dietrich and J. Dixon

Dietrich, J.R. and Dixon, J., 1996. Geology of the Beaufort Sea Continental Shelf. In The Geology, Mineral and Hydrocarbon potential of Northern Yukon Territory and Northwestern District of Mackenzie. Geological Survey of Canada, Bulletin 422, p. 319–332.

Abstract

The Beaufort Sea and the adjacent land area have been explored for hydrocarbons since the mid 1960s; about 250 exploration wells have been drilled and data from many tens of thousands of kilometres of seismic reflection surveying have been recorded.

Under the southeastern Beaufort shelf there are an estimated 15 to 20 km of Proterozoic to Paleozoic strata resting on crystalline basement. These are overlain by 2 to 3 km of Jurassic to Albian strata, generally preserved in half-grabens. Pre-Upper Cretaceous strata are overlain by a thick succession of sediments of the Cenomanian to Holocene continental terrace-wedge, which is 12 to 16 km thick under the eastern Beaufort Sea. Pre-Upper Cretaceous strata thin rapidly oceanward. A transitional to oceanic crust is interpreted as underlying the terrace-wedge sediments approximately 100 km offshore from Tuktoyaktuk Peninsula.

The Tertiary offshore strata are folded in an arcuate array that parallels the onshore structures of the northern Yukon. These folds are cut by contraction faults in the western Beaufort Sea and by younger listric growth faults throughout the area. A 30 km wide rift zone underlies the continental terrace-wedge sediments in the northeastern part of the area, in which there are two main fault/hinge lines, the inner Eskimo Lakes Fault Zone and an Outer Hinge Line.

Oil and gas occur in large quantities and the potential looks promising. The bulk of the discovered resources are in Tertiary sandstone reservoirs, with lesser amounts in Lower Cretaceous sandstones.

Résumé

Depuis le milieu des années 1960, on explore la mer de Beaufort et la région continentale adjacente à la recherche d'hydrocarbures; on a foré 250 puits d'exploration environ et enregistré des données de sismique réflexion sur des dizaines de milliers de kilomètres.

Sous la plate-forme continentale du sud-est de la mer de Beaufort, on a évalué qu'entre 15 à 20 km de couches protérozoïques à paléozoïques reposaient sur un socle cristallin. Ces couches sont surmontées de 2 à 3 km de couches jurassiques à albiennes, généralement conservées dans des demi-grabens. Les couches antérieures au Crétacé supérieur reposent sous une épaisse succession de sédiments de terrasse continentale-biseau du Cénomanien à l'Holocène qui mesure de 12 à 16 km sous l'est de la mer de Beaufort. Les couches antérieures au Crétacé supérieur s'amincissent rapidement vers l'océan. Une croûte transitionnelle à océanique s'étendrait sous les sédiments de terrasse-biseau à environ 100 km au large de la péninsule de Tuktoyaktuk.

Les couches tertiaires reposant au large sont plissées en un alignement arqué qui est parallèle aux structures littorales du nord du Yukon. Ces plis sont entaillés par des failles de contraction dans l'ouest de la mer de Beaufort et par des failles listriques synsédimentaires plus récentes dans toute la

région. Une vaste zone d'effondrement de 30 km de largeur s'étend sous les sédiments de terrasse continentale-biseau dans la partie nord-est de la région dans laquelle on observe deux principales lignes de faille/charnière, soit la zone de failles intérieure d'Eskimo Lakes et une ligne de charnière extérieure.

Le pétrole et le gaz sont abondants et le potentiel semble prometteur. Les ressources découvertes sont en grande partie présentes dans des réservoirs de grès tertiaires, et des quantités moindres occupent des grès du Crétacé inférieur.

INTRODUCTION

The area of the Beaufort Sea discussed in this chapter extends from Amundsen Gulf westward to the U.S. border, at the 141st meridian (Fig. 12.1). On the southern rim lies the coastal plain of northern Yukon, and the Mackenzie Delta and Tuktoyaktuk Peninsula of the Northwest Territories. To the north lies the oceanic Canada Basin which is up to 4000 m deep.

The continental margin can be divided into several physiographic elements. The continental shelf is 50 to 100 km wide and is characterized by low, uniform shelf gradients of 1 to 2 m/km. An abrupt increase in slope gradient marks the shelf-edge, which occurs at varying water depths, from 60 m near longitude 141°W to about 200 m near Amundsen Gulf. On the western part of the shelf there is a northwest trending, 200 to 300 m deep channel, the Mackenzie Trough, that extends inboard almost to the Yukon coast. The continental slope is 20 to 50 km wide and has variable slope gradients of 5 to 30 m/km. North of Mackenzie Trough, the outer continental slope has gradients up to 170 m/km. In Alaskan waters, this outer slope has

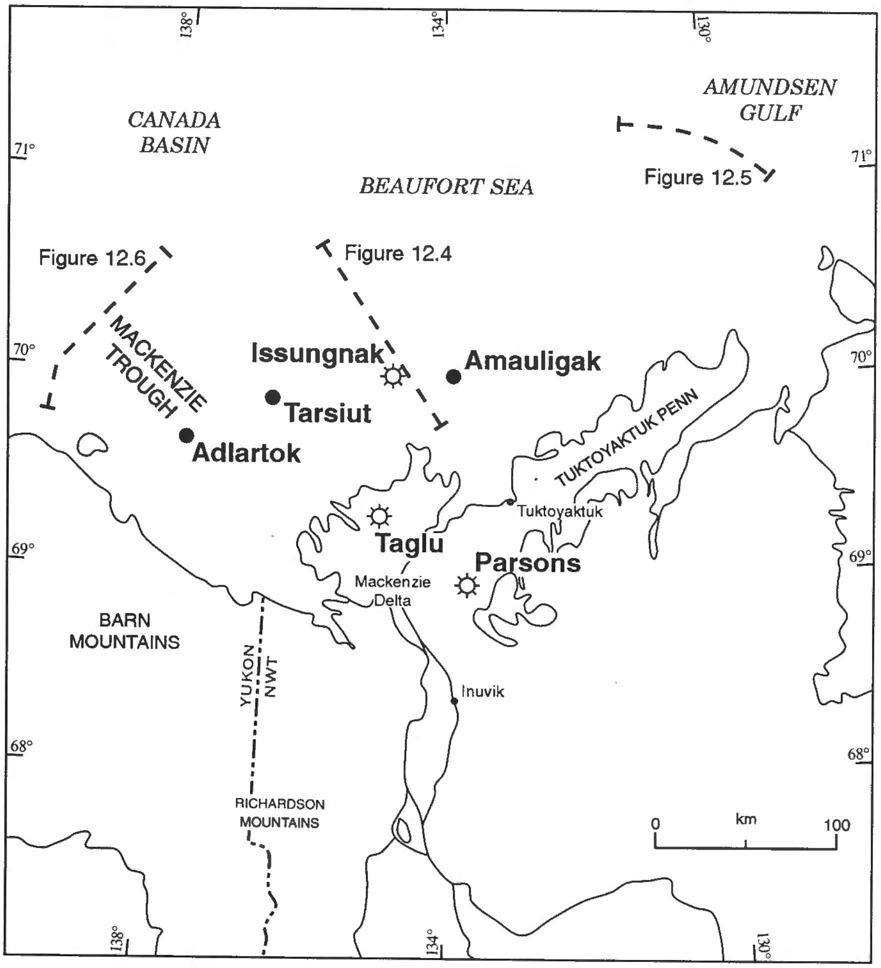

Figure 12.1. Geography and physiographic elements. Locations of Figures 12.4, 12.5 and 12.6 are indicated.

been called the Beaufort Ramp (Grantz et al., 1981). The continental rise begins at water depths of 1100 to 1800 m and extends for several hundred kilometres into the Canada Basin. Slope gradients on the rise are 10 to 15 m/km. The permanent ice pack covers much of the area underlain by the continental rise.

Data from several tens of thousands of kilometres of marine seismic reflection surveying are available and about 250 exploration boreholes have been drilled onshore and offshore. These petroleum industry data are available to the public and form the basis for most of our understanding of the supracrustal geology. Well data are available for viewing at the Geological Survey of Canada (Institute of Sedimentary and Petroleum Geology), Calgary, and seismic data can be purchased from the National Energy Board, Calgary. The Geological Survey of Canada has acquired data from several hundred kilometres of deep seismic reflection surveying (Cook et al., 1987a, b; Dietrich et al., 1989a), the tapes for which are available for copying.

PREVIOUS WORK

Early geological syntheses that attempted to incorporate data from the continental margin were compiled by Lerand (1973), Yorath (1973), and Yorath and Norris (1975). These early reports still relied mostly upon land-based data, with only a minor amount of data from the offshore. With increased exploration activity in the Mackenzie Delta and offshore areas, more data became available, especially after 1980 when seismic reflection data were released for public viewing. Some of the early reports that began to utilize the new information include Hawkings and Hatlelid (1975) and Young et al. (1976). As exploration began to move offshore, reports on individual wells began to appear (Dixon and Snowdon, 1979; Jones et al., 1980; McNeil et al., 1982; Dixon et al., 1984; James and Baxter, 1988; Dietrich et al., 1989b). Stratigraphic nomenclature took diverging paths; Young and McNeil (1984) proposed lithostratigraphic divisions for Tertiary strata under the Mackenzie Delta, whereas Dietrich et al. (1985) and Hubbard et al. (1987) proposed the use of seismic/depositional sequences. More recent stratigraphic syntheses have included Hea et al. (1980), Willumsen and Coté (1982), Dixon et al. (1985), Dixon (1986), Dixon and Dietrich (1990), and Dixon et al. (1992). Norris and Yorath (1981) and Balkwill et al. (1983) included the Beaufort Sea area in their syntheses, although these two reports rely mostly on land-based data.

STRUCTURAL SETTING

The Beaufort–Mackenzie Basin comprises Upper Cretaceous to Holocene, continental terrace-wedge sediments resting on a pre-Upper Cretaceous basement (Dixon et al., 1985, p. 4; Dixon et al., 1992). At the southeast basin margin, the basement consists of 15 to 20 km of Proterozoic and Lower Paleozoic strata, underlain by crystalline basement and overlain by 2 to 3 km of Jurassic to Albian strata (Cook et al., 1987a, b). The depth of the Moho is estimated to be 35 to 37 km under the southeast margin, rising oceanward to 20 to 25 km under the outer shelf and slope (Cook et al., 1987a, b). The deep crustal structure of the western Beaufort Sea continental margin is poorly understood due to inadequate or ambiguous geophysical information.

Underlying the eastern Beaufort shelf are an estimated 12 to 16 km of sediments, the bulk of which are probably Upper Cretaceous to Holocene sediments (Fig. 12.2) of the Beaufort–Mackenzie Basin. These sediments form part of the uncompensated sediment column that underlies the large positive gravity anomaly along the continental margin (Sobczak, 1975). Underlying the thickest accumulation of sediment are pre-Upper Cretaceous rocks whose geophysical properties suggest they are transitional between continental and oceanic crust (Dietrich et al., 1989a).

The Upper Cretaceous to Miocene succession beneath the west and central Beaufort Sea is folded into broad, low amplitude folds that are part of a larger, arcuate fold belt (Fig. 12.3). Under the inner, and most of the outer shelf, these folds are cut by younger listric faults that strike at high angles to the fold axes (Figs. 12.3, 12.4). Pliocene to Holocene strata are undeformed to only mildly deformed and rest with marked unconformity on older folded and faulted strata. Deformation of Upper Cretaceous to Miocene strata decreases northeastward, and off Amundsen Gulf the succession contains only a few faults and minor folding.

Southeast of the central Beaufort shelf, the Upper Cretaceous to Holocene sedimentary succession thins rapidly, especially across two hinge lines, the inner Eskimo Lakes Fault Zone (also known as the Arctic Platform Hinge Line) and Outer Hinge Line (Figs. 12.3, 12.5; Dixon et al., 1985, fig. 2; Dixon and Dietrich, 1990, figs. 16–2, 16–10). These hinge lines correspond with fault zones that have their strongest expression in pre-Upper Cretaceous strata. The inner hinge line can be traced into the Eskimo Lakes Fault Zone underlying Tuktoyaktuk Peninsula (Fig. 12.3). The Eskimo Lakes Fault Zone is a narrow zone of

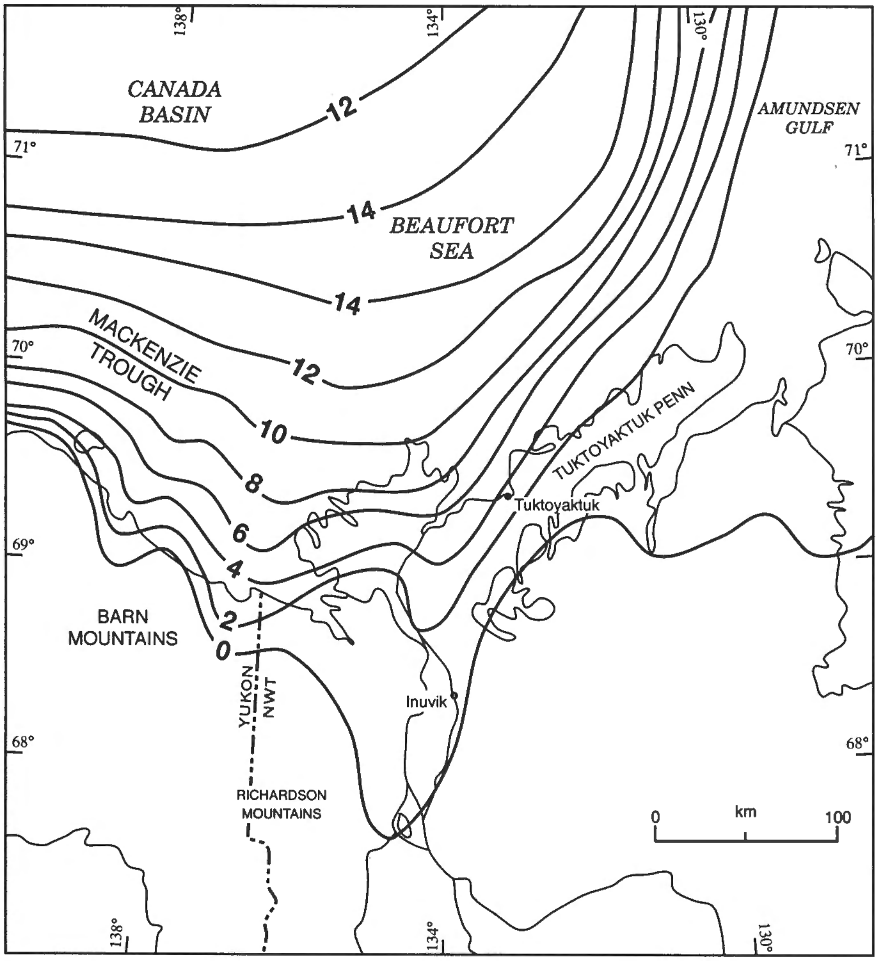

Figure 12.2. *Isopach (1000 m intervals) of the Beaufort–Mackenzie basin-fill: predominantly Upper Cretaceous to Holocene sediments, but may include some older Mesozoic strata. Thicknesses were determined from well data and interpretation of seismic reflection data.*

extension faults in which pre-Upper Cretaceous strata have been downfaulted to the north by considerable amounts, whereas Late Cretaceous and younger strata are offset by much less (Cook et al., 1987a, b). The southeastern basin margin is underlain by Mesozoic (Dixon, 1982), Lower Paleozoic (Wielans, 1988), and a thick, highly deformed Proterozoic succession (Cook et al., 1987a, b).

West of Mackenzie Delta, the pre-Tertiary stratigraphy and structure under the shelf are masked by a thick and highly deformed Tertiary succession. Pre-Pliocene strata are deformed into an arcuate array of folds that closely parallels the fold trends in older strata on land (Fig. 12.3; Lane, 1988). The inboard folds tend to be asymmetric with the steeper limb on the north side, commonly cut by a thrust fault (Fig. 12.6). The folds become more symmetric northward and contraction faults are less common. Younger listric normal faults locally cut through the succession. Within this fold belt are four large-scale structural features: the Herschel, Natsek and Blow River highs, and the Demarcation sub-basin (Fig. 12.3). The highs are defined principally by the elevation of a mid-Eocene unconformity relative to adjacent areas. In the Herschel and Blow River highs, pre-Middle Eocene strata contain closely spaced, faulted anticlines that appear to have been uplifted en masse in the Middle Eocene and again in the late Miocene. The Natsek High (Dietrich et al., 1989b) is linked to the Herschel High, but the pre-Middle Eocene strata are not as intensely deformed as in the Herschel High. Demarcation sub-basin is a synclinal feature which contains Middle Eocene to Miocene strata and is truncated by flat-lying to gently oceanward-dipping Pliocene to Holocene strata.

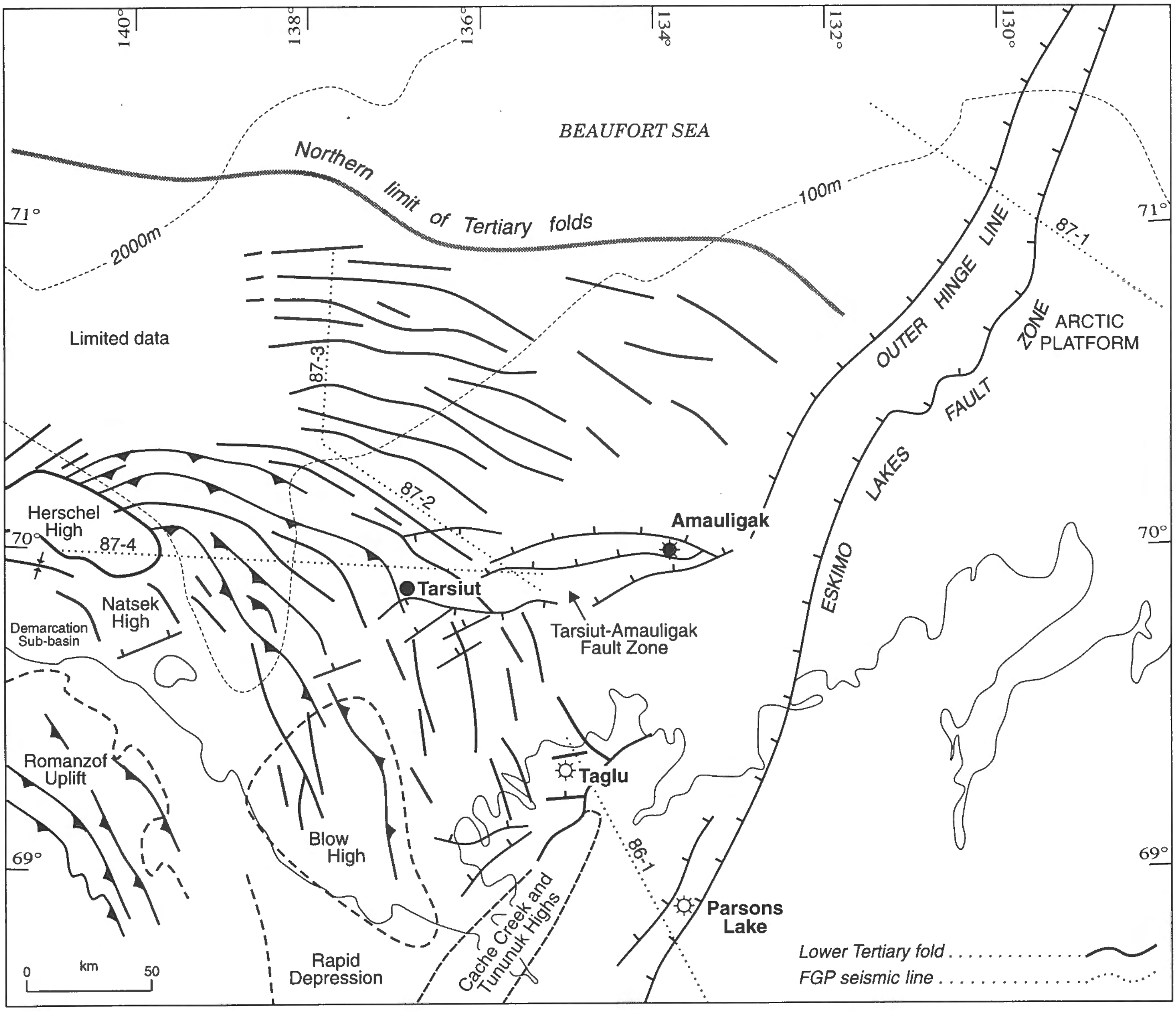

Figure 12.3. *Structural trends and elements, Beaufort–Mackenzie Basin. The 100 m isobath is the approximate shelf edge.*

STRATIGRAPHY

Only under the inner shelf and the adjacent land areas is there an opportunity to discern pre-Tertiary strata (Fig. 12.7; see other chapters in this publication). Proterozoic strata are exposed at Campbell Uplift (Norris and Black, 1964; Dyke, 1975) near Inuvik. They are known to subcrop under Tuktoyaktuk Peninsula (Wielans, 1988), where they may be as thick as 10 to 15 km (Cook et al., 1987a, b), although some of the thickening may be due to thrust repetition. The known lithotypes are mostly phyllite, chert and quartzose sandstone with minor occurrences of volcanic rock. Interpretation of deep seismic reflection data (Cook et al., 1987a, b; Dietrich et al., 1989a) indicates that the Proterozoic thins rapidly oceanward. The Neruokpuk Formation in the British Mountains has been considered to be Proterozoic (Norris, 1985), but recent work has shown that a considerable amount of Neruokpuk strata on the northeast flank of Romanzof Uplift is lower Paleozoic basinal phyllitic shale and chert (Lane and Cecile, 1989), which are correlative with similar strata in the adjacent Barn Mountains to the east (Lenz and Perry, 1972; Cecile, 1988). Lower Paleozoic and Devonian strata outcrop in Campbell Uplift and adjacent areas (Dyke, 1975; Norris, 1981), and are present under Tuktoyaktuk Peninsula (Wielans, 1988). Most of the Cambrian to

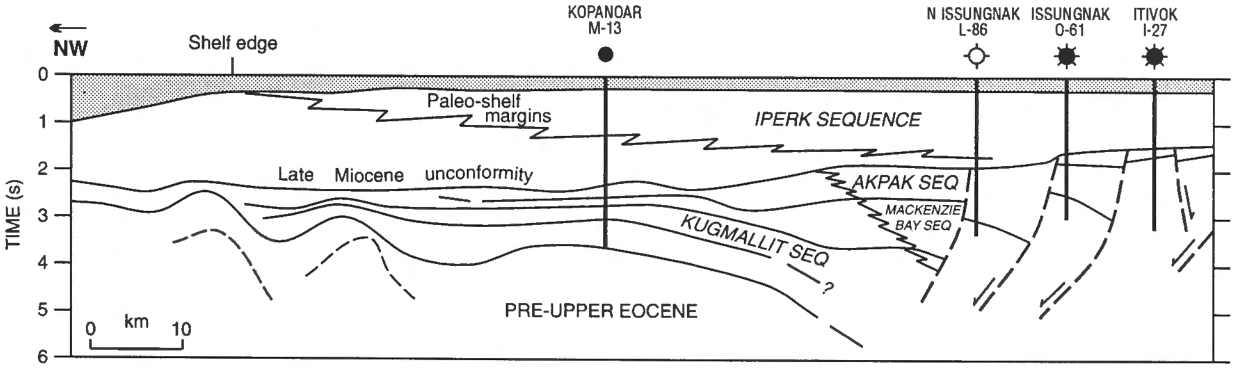

Figure 12.4. Structural-stratigraphic cross-section, central Beaufort Sea (based on the interpretation of seismic reflection data).

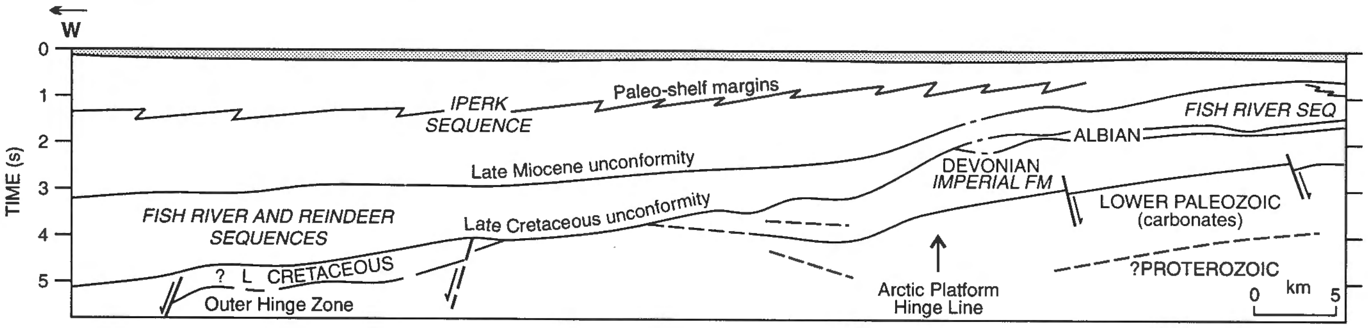

Figure 12.5. Structural-stratigraphic cross-section, eastern Beaufort Sea (based on the interpretation of seismic reflection data).

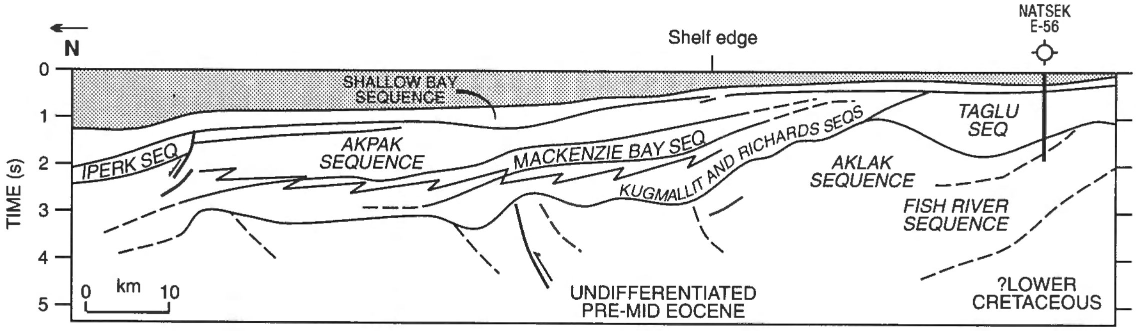

Figure 12.6. Structural-stratigraphic cross-section, western Beaufort Sea (based on the interpretation of seismic reflection data). The Late Miocene unconformity identified on Figures 12.4, 12.5 and 12.6 occurs at the base of the Shallow Bay–Iperk sequences.

Middle Devonian strata in the eastern area are platform carbonates with a few wells penetrating equivalents of the basinal shale succession of the Road River Formation (Fig. 12.7). Upper Devonian strata consist of a thick clastic succession of the Imperial Formation. Cambrian to Devonian and, to a lesser extent, Proterozoic successions can be traced under the eastern inner shelf areas using seismic reflection data.

Carboniferous and Permian strata are known only in the Romanzof, Barn, White and Cache Creek uplifts, and in the subsurface of southwestern Mackenzie Delta (Fig. 12.7). The general succession consists of basal clastics (Kayak and Kekiktuk formations) overlain by carbonates of the Lisburne Group, in turn succeeded by unnamed Permian clastics and local carbonates. There is northward to

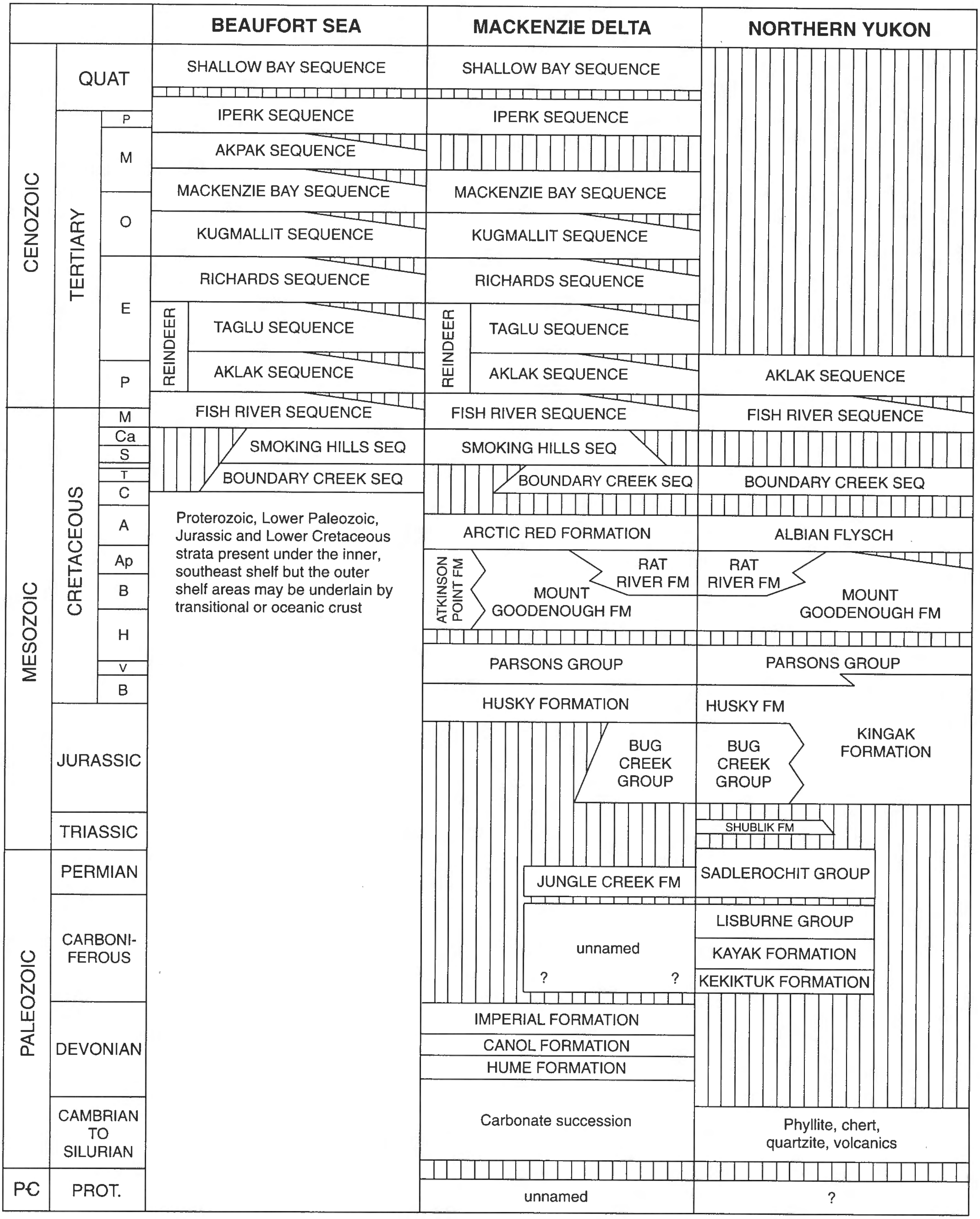

Figure 12.7. *Stratigraphic chart, Beaufort–Mackenzie area.*

northeastward thinning and sub-Triassic truncation on the Romanzof Uplift, which is not apparent in the Cache Creek Uplift (Chapter 3) and adjacent subsurface. The northward extent of upper Paleozoic strata under the western Beaufort shelf is not known, but the truncation trends suggest that they may be thin to absent.

Mesozoic strata are better known, especially on the land areas and under the southern Mackenzie Delta and Tuktoyaktuk Peninsula (Fig. 12.7; Dixon, 1982; Dixon et al., 1989). Triassic limestone and sandstone of the Shublik Formation are thin and have a limited distribution in the British and Barn mountains. The local occurrence of Triassic strata suggests that Triassic beds are either extremely thin or not present under the western continental shelf. Jurassic to Albian strata, on the other hand, are thick and extensive, and are known to be present locally under the shelf in the eastern Beaufort Sea. The extremely thick Jurassic to Albian succession in Rapid Depression (possibly 5-8 km thick) favours its presence at least under the inner shelf of the western Beaufort Sea. Interpretation of deep seismic reflection data from the southwestern end of Tuktoyaktuk Peninsula indicates basinward erosion of Lower Cretaceous and older strata (Cook et al., 1987a, b; Dietrich et al., 1989a), suggesting that their presence under the shelf may be limited to the inner shelf area. Local preservation in half-grabens under the southeastern inner shelf has been interpreted from industry seismic reflection data. The Jurassic to Albian succession consists of alternating shale- and sandstone-dominant formations under Tuktoyaktuk Peninsula and throughout the northern Richardson Mountains, becoming progressively shalier to the west and northwest in the Blow River and British Mountains areas. Up until the mid-Aptian, sedimentation was dominated by shelf deposition (Young et al., 1976; Dixon, 1988). Toward the end of the Aptian, there was a drastic change in the depositional regime; deep-water troughs formed under parts of Tuktoyaktuk Peninsula (Kugmallit Trough) and along the Rapid Depression (Blow Trough) (Dixon, 1986; Dixon et al., 1989). These basinal troughs have been interpreted to be the result of a major phase of extensional faulting, possibly accompanied by orogenic crustal loading from the west (Dixon, in press).

The bulk of the known strata under the Beaufort shelf is Upper Cretaceous to Holocene. Dietrich et al. (1985) originally identified eleven basinwide sequences, with some subsequent additions and modifications (Fig. 12.7; Dietrich et al., 1989b; Dixon and Dietrich, 1988, fig. 2; Dixon et al., 1992). Most sequences represent a major progradational sedimentary succession dominated by deltaic deposition at the basin margin, grading basinward into shale-dominant successions of shelf, slope and basinal origin. Two of the identified sequences, the Boundary Creek and Smoking Hills sequences, are represented by organic-rich slope and basinal shales, the deltaic and shelf equivalents of which are much farther to the south, under Eagle Plain (Dixon, 1992). The first of these major deltaic successions in the Beaufort-Mackenzie area is the Paleocene part of the Fish River Sequence (sandstone member of the Moose Channel Formation), which outcrops in the northern Richardson Mountains and along parts of the Yukon coastal plain. Fish River delta plain and delta front strata are known to be present as far west as the Natsek E-56 well (Dietrich et al., 1989b), and seismic correlations suggest similar strata are present between the two known areas. If correct, then the Paleocene delta complex covered a large area of the western Beaufort Sea.

Succeeding deltaic successions, until the Oligocene, tended to migrate eastward to northeastward, and slightly more basinward than preceding deltas (Fig. 12.8). Four of the Paleocene to Pliocene sequences are known to contain significant lowstand deposits of submarine canyon and fan origin. These deposits are in the Fish River (Cuesta Creek member of the Tent Island Formation; Dixon, 1988), Taglu (unnamed strata in the Edlok N-56 well; Dietrich et al., 1989b), Kugmallit (Dixon et al. 1984; Dietrich et al., 1985), and Iperk sequences (Dixon et al., 1984). Lowstand deposits in the Kopanaor well were originally identified as a separate depositional sequence (Dixon et al., 1989; Dietrich et al., 1985), but they are now recognized as part of the Kugmallit Sequence, to which they are now assigned. In the Miocene Mackenzie Bay and Akpak sequences, no deltaic depocentres have been identified in the Canadian Beaufort Sea, both are represented by mudstone-dominant shelf, slope, and basinal deposits. Thickness trends for the two Miocene sequences indicate a western depocentre. During the Pliocene and possibly early Pleistocene, the depocentre and accompanying delta complexes switched to the east.

The Tertiary succession tends to be overpressured in many areas. Overpressuring is possibly a dewatering phenomenon and is not related to basin-margin freshwater recharge (B. Hitchon, pers. comm., 1988). Sandstones in much of the Tertiary succession are predominantly litharenites and tend to be weakly cemented, even to depths approaching 5 km. Petrographic studies by Schmidt (1987) suggest that a considerable amount of cement and primary grains have been removed.

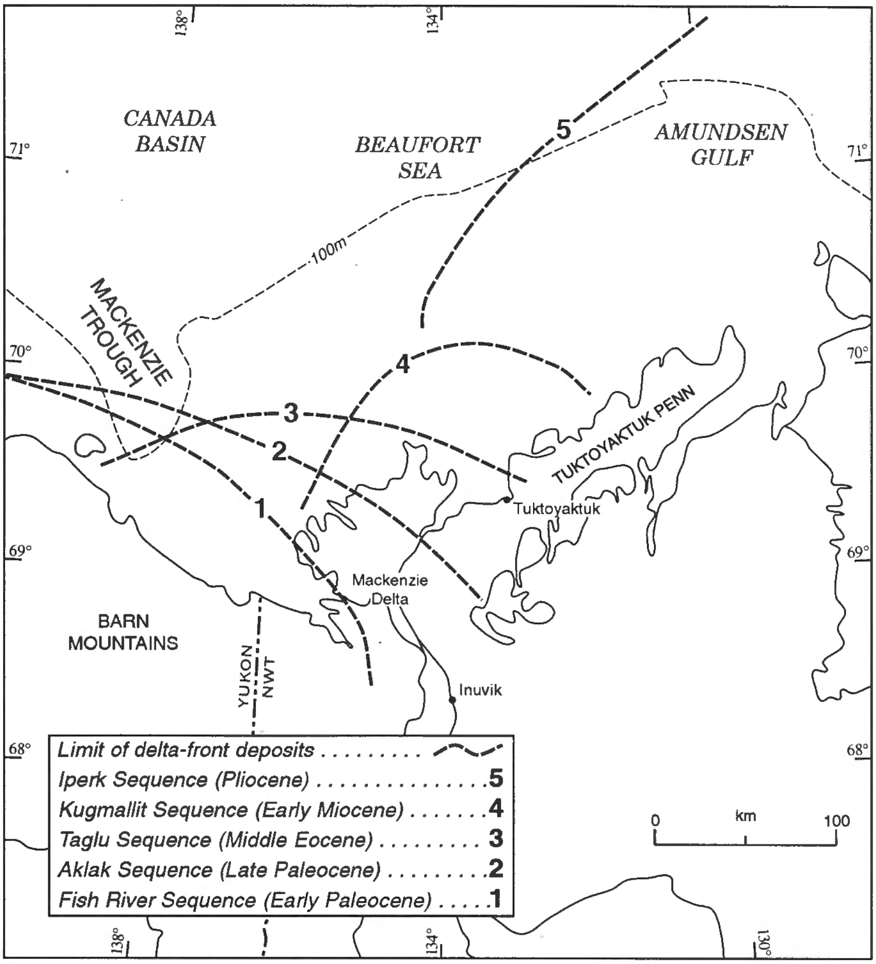

***Figure 12.8.** Migration of Tertiary delta complexes. The 100 m isobath is the approximate position of the modern shelf edge.*

TECTONIC DEVELOPMENT

The southeastern continental margin of the Beaufort Sea appears to be a typical extensional margin (Cook et al., 1987a, b; Dietrich et al., 1989a) that developed prior to the Cenomanian, whereas the southwestern margin has been overprinted by Tertiary compressional deformation. However, the geological history of the whole area, inclusive of the land areas, would strongly favour an extensional history for the southwestern margin during the Jurassic to Albian (Chapter 11). The Alaskan shelf west of Demarcation Bay also has features typical of an extensional margin (Grantz et al., 1979). If the available data have been correctly interpreted, then any plate tectonic model has to account for these features.

Four basic plate tectonic models have been advocated for the origin of Canada Basin (see review by Lawyer et al., 1984), these are:

1. Counter-clockwise rotation of northern Alaska away from the Canadian Arctic Islands (e.g., Carey, 1955; Tailleur, 1973; Grantz et al., 1979; Rowley and Lottes, 1988).

2. Southward strike-slip of northern Alaska along the Arctic Islands continental margin (e.g., Hubbard et al., 1987; Smith, 1987; Crane, 1987).

3. Westward movement of a continental plate (''Kolymski'' or ''Novosibirsk'' plate) out of the area occupied by Canada Basin (e.g., Herron et al., 1974; Metz et al., 1982).

4. Northward movement of northern Alaska, first along the Tintina Fault and then the Kaltag Fault (Jones, 1982).

There have been advocates of a more ''fixist'' hypothesis, wherein the relative positions of continental and oceanic areas have remained relatively constant throughout the Phanerozoic, or the greater part thereof (e.g., Meyerhoff, 1973). Also, some workers have proposed that the Arctic Ocean is a Paleozoic feature (e.g., Churkin and Trexler, 1981). However, for the purposes of this discussion we will assume that some ocean-forming processes operated during the Mesozoic to produce the Canada Basin.

Of the four models, the strike-slip and the Jones (1982) models do not fit the known data. The presently available seismic and geological data indicate that the continental margin off the Arctic Islands and northeast of Mackenzie Delta appears to be extensional. Also, both models have northern Alaska and the northwesternmost part of the Yukon displaced hundreds of kilometres from their present positions; the Phanerozoic geology does not support this amount of motion. There is a common geology between northern Alaska/northwestern Yukon and the areas to the southeast and south, which implies that, although some lateral displacement can have occurred, the two areas have not been offset by hundreds of kilometres.

Only the rotation model and the continental land body moving out of the Canada Basin retain the requisite geological continuity between northern Alaska and adjacent Canada. However, in the case of the latter model, the northern Alaska margin would have to be a strike-slip zone, or at best an oblique-slip fault zone; the available data do not seem to support such a margin (Grantz and May, 1983). The rotation model probably has found the most adherents, but this model does have some problems. The two most serious problems are the location of a suitable suture zone in the USSR, which this model requires, and whether or not the detailed geology of such a suture fits the model's premises. A lack of available detailed geological data from Siberia and the adjacent Siberian shelf has been a serious problem in the testing of the hypothesis. The timing of the onset of continental drift also has been another contentious issue, with ages ranging from Barremian (Grantz et al., 1979) to Albian (Craig et al., 1985) and Cenomanian (Dixon, in press; Embry and Dixon, 1990). The timing of drift onset usually has been estimated by dating the end of major extensional faulting which generally results in the formation of a breakup unconformity. Along the Alaskan Beaufort Sea, extensional faults appear to die out at the base of the Pebble Shale, suggesting a middle or late Hauterivian age (Grantz et al., 1983). Craig et al. (1985) used the top of the Pebble Shale as the breakup unconformity and dated it as Early Albian. On the Canadian margin of the Amerasia Basin, most of the major extensional faulting ended by the close of Albian time (Embry and Dixon, 1991). Embry and Dixon (1990) explained the dichotomy of evidence between Alaska and Canada by suggesting that Albian foreland basin development in northern Alaska subdued fault activity, whereas on the Canadian margin, Albian sedimentation was less intense and extensional faulting continued into the Albian.

ECONOMIC GEOLOGY

Considerable oil and gas have been found in the sediments of the continental margin and the hydrocarbon potential makes the Beaufort Sea an economically very important area for further exploration (Dixon et al., 1988). To date, hydrocarbons have been recovered from lower and upper Paleozoic rocks, and Lower Cretaceous and Paleocene to Miocene strata, although the bulk of the known reserves are in Eocene and Oligocene rocks. The major fields are Parsons (gas in the Neocomian Parsons Group), Taglu (gas and condensate in the Eocene Taglu Sequence), Issungnak (gas in the Oligocene Kugmallit Sequence), Tarsiut (oil in the Kugmallit Sequence), and Amauligak (oil and gas in the Oligocene Kugmallit Sequence) (Fig. 12.1).

The trap types vary according to basin position. Along the southeastern basin-margin, structural closure of pre-Cenomanian strata against extension faults form important hydrocarbon traps. Under Mackenzie Delta and the immediate offshore areas, closure of strata against listric growth faults is the main trap type. In the far offshore and the west Beaufort Sea, the known hydrocarbon occurrences are associated with compressional anticlines.

The best reservoirs to date have been in delta front sandstones. These sandstones have good porosity, commonly 20 to 25 per cent, and generally good lateral continuity across structures. Most reservoirs in Tertiary strata occur at or near the top of thick delta front successions. Top seal is usually a thick, overlying, shale-dominant interval, and in listric-fault traps, lateral seal also is a thick, structurally juxtaposed shale succession.

Tertiary strata are dominated by terrestrially derived organic material, with marine organic matter in the Boundary Creek and Smoking Hills sequences (Snowdon, 1980, 1985). Organic content is low in the Tertiary successions, generally less than 2 per cent organic carbon. The Boundary Creek and Smoking Hills successions are very rich, with organic carbon in outcrop samples of the Smoking Hills Sequence measuring up to 12 per cent, but generally averaging 3 to 5 per cent. Although the richest potential source rocks are Upper Cretaceous, they do not appear to have been the source for much of the discovered resources. Only a few relatively small oil discoveries along the Tuktoyaktuk Peninsula and the adjacent offshore can be attributed to upper Cretaceous source rocks (Snowdon and Powell, 1979); for example Tuk L-09, Atkinson H-25, Imnak J-29, and Mayogiak J-17. The oil discoveries with an Upper Cretaceous source rock are principally in Lower Cretaceous reservoirs, with two in fractured lower Paleozoic carbonates. Most of the discovered oil resources are in Tertiary reservoirs; biomarker analysis suggests that the oil is derived from shales in the lower part of the Richards Sequence (Brooks, 1986). The only known exception is the oil at Adlartok P-09, in the west Beaufort Sea. Adlartok is the only hydrocarbon discovery in the poorly explored west Beaufort Sea and its source rock has not yet been identified. The large volumes of gas in Tertiary reservoirs are presumed to have been derived from Tertiary shales, whereas the gas in the Lower Cretaceous sandstones at Parsons gas field may have been derived from the Middle Jurassic to Berriasian Husky Formation (Langhus, 1980).

Maturation levels are generally low in the drilled Tertiary strata, although at the basin margins the older successions are generally at much higher levels, in some instances overmature. The lower maturation levels are consistent with the low heat flow in the Beaufort-Mackenzie Basin (Majorowicz and Dietrich, 1989). Work by Issler and Snowdon (1990), on kinetic modelling of hydrocarbon generation in the Beaufort-Mackenzie Tertiary succession, suggests that hydrocarbon generation occurs at a depth of 4.5 to 6.5 km in the central Beaufort Sea area. The low maturation levels in the drilled intervals (4-5 km depth) and the predicted rapid increase in maturation below these depths is explained as the result of depression of the isotherms by recent (<5 Ma) high rates of sedimentation.

Petroleum resources in the Beaufort-Mackenzie area are estimated to be in the order of 985.7 to 1240.1 x $10^6 m^3$ (6.2-7.8 x 10^9 barrels) of oil and 1.6 to 2.1 x $10^{12} m^3$ (57.5-73.1 TCF) of gas at the 75 and 25 per cent probability levels (Dixon et al., 1988). These values include all pool sizes, and whether or not the plays are economically or technologically viable. If only the onshore and shallow water shelf — areas where exploration is technologically feasible — in the central Beaufort-Mackenzie area are considered, the mean expectation is for 699.5 x $10^6 m^3$ (4.4 x 10^9 barrels) of oil and 0.79 x $10^{12} m^3$ (28 TCF) of gas (Dixon et al., 1988). The west Beaufort Sea remains a largely untested area and is believed to have considerable potential.

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CHAPTER 13

WHITE, BARN AND CAMPBELL UPLIFTS

L.D. Dyke

Dyke, L.D., 1996. White, Barn and Campbell Uplifts. In The Geology, Mineral and Hydrocarbon Potential of Northern Yukon Territory and Northwestern District of Mackenzie, Geological Survey of Canada, Bulletin 422, p. 333–358.

Abstract

Barn, White, and Campbell uplifts are structural components of the northernmost Canadian Cordillera. The three have maximum plan dimensions ranging from 12 to 25 km and display structural relief of up to 3.5 km. Barn Uplift is a horizontally shortened and tilted block consisting mainly of Paleozoic argillite and chert. It is structurally conformable in the west but fault bounded in the east. White Uplift is a raised block of completely fault-bounded Paleozoic carbonates. Campbell Uplift is a broad dome broken into raised and lowered blocks by traversing faults. All three uplifts are parts of structural components of more regional extent and appear to be localized by pre-existing changes in the mechanical or geometric properties of the stratigraphic package.

Résumé

Les soulèvements de Barn, de White et de Campbell sont des composantes structurales de l'extrême nord de la Cordillère canadienne. Tous les trois ont des dimensions maximales en plan variant de 12 à 25 km et un relief structural atteignant 3,5 km. Le soulèvement de Barn est un bloc horizontalement raccourci et basculé composé principalement d'argilite et de chert du Paléozoïque. Il est structuralement concordant dans l'ouest mais il est limité par des failles dans l'est. Le soulèvement de White est un bloc soulevé de roches carbonatées paléozoïques complètement limitées par des failles. Le soulèvement de Campbell est un vaste dôme fracturé en blocs soulevés et abaissés par des failles transversales. Les trois soulèvements font partie de composantes structurales d'étendue plus régionale et semblent être localisés par des changements préexistants dans les propriétés mécaniques ou géométriques de l'ensemble stratigraphique.

INTRODUCTION

The northernmost Canadian Cordillera is a complexly deformed belt characterized by an association of diverse depositional and tectonic environments. Barn, White, and Campbell uplifts, which are small components of this belt, provide an opportunity to analyse features resulting from the interaction of these regimes. Having been breached by erosion, they hold little or no trapping potential for hydrocarbons. However, these uplifts may supply clues to the recognition of similar features at structural levels more conducive to the retention of hydrocarbons, for example on the Beaufort Shelf.

The deformation of sedimentary sequences is easiest to analyse when laterally persistent rock units are present. However, facies changes are a common feature on a regional scale in the northern Canadian Cordillera and the inherent mechanical contrasts are likely to influence deformation. It is reasonable to expect, therefore, that the structural complexity of the northern Cordillera results, in part, from the discontinuous nature of the stratigraphic units. The role of stratigraphic discontinuities in the structural evolution of the region can be investigated by studying areas where deformation is pronounced. This chapter investigates the relationship between the three uplifts and pre-existing stratigraphy. The three uplifts differ greatly in structural style, structural relief and relation to surrounding structural trends. However, all three are thought to occur where horizontal compression has produced structural relief localized by sedimentary facies changes or changes in depositional thickness.

REGIONAL GEOLOGIC SETTING OF THE UPLIFTS

The positions of the uplifts can be related to the major structural elements of the northernmost Canadian Cordillera as described by Norris (1973) and Norris and Yorath (1981). The northeast-trending Aklavik Arch is a complex of uplifted and depressed components in which a history of intermittent tectonic activity beginning at least as early as late Proterozoic is recorded. Both White and Campbell uplifts are part of this feature (Fig. 13.1) along with Dave Lord, Cache Creek and Rat uplifts. Some of the uplifts have exposed cores with strata as old as Proterozoic. Norris (1974) describes five angular unconformities within the arch which confirm episodes of uplift from late Proterozoic to Cretaceous or early Tertiary time. Barn Uplift lies to the north, separated from Aklavik Arch by Rapid Depression. It is separated from Romanzof Uplift by Old Crow–Babbage Depression but contains structural trends related to both Romanzof Uplift and Rapid Depression.

Barn, White, and Campbell uplifts have cores dominated by lower Paleozoic rocks (Fig. 13.2). The exposed rock types reflect the paleophysiography described by Lenz (1972) for the early Paleozoic. Barn Uplift exhibits sequences of fine grained clastics and scattered intervals of carbonates and coarser clastics which probably total at least 3000 m in thickness. These lithologies imply a deep basin or basin margin environment and occupy part of what Lenz named the British–Barn Mountains Trough. Both White and Campbell uplifts, on the other hand, have cores consisting totally or mostly of carbonates, most massively bedded and finely crystalline. At White Uplift, erosion of the carbonates into castellate forms suggestive of extensive biohermal development is common. At both White and Campbell uplifts, coral and brachiopod faunas are scattered throughout. These characteristics point to a shelf margin or shallow-water origin on the platform that existed between the British–Barn Mountains Trough and Richardson Trough (Lenz, 1972). Where more stratigraphic data are available, it becomes clear that a second order of

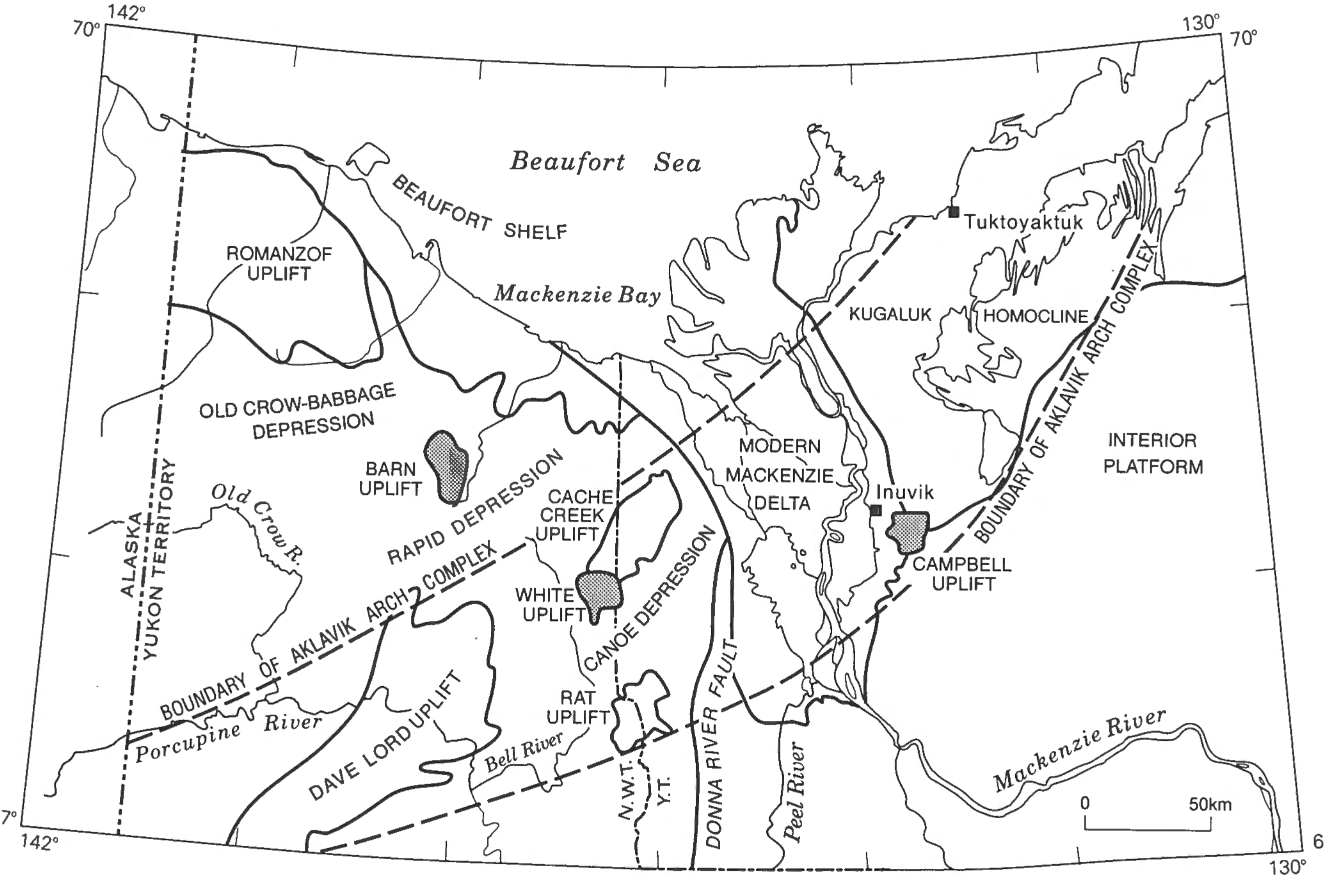
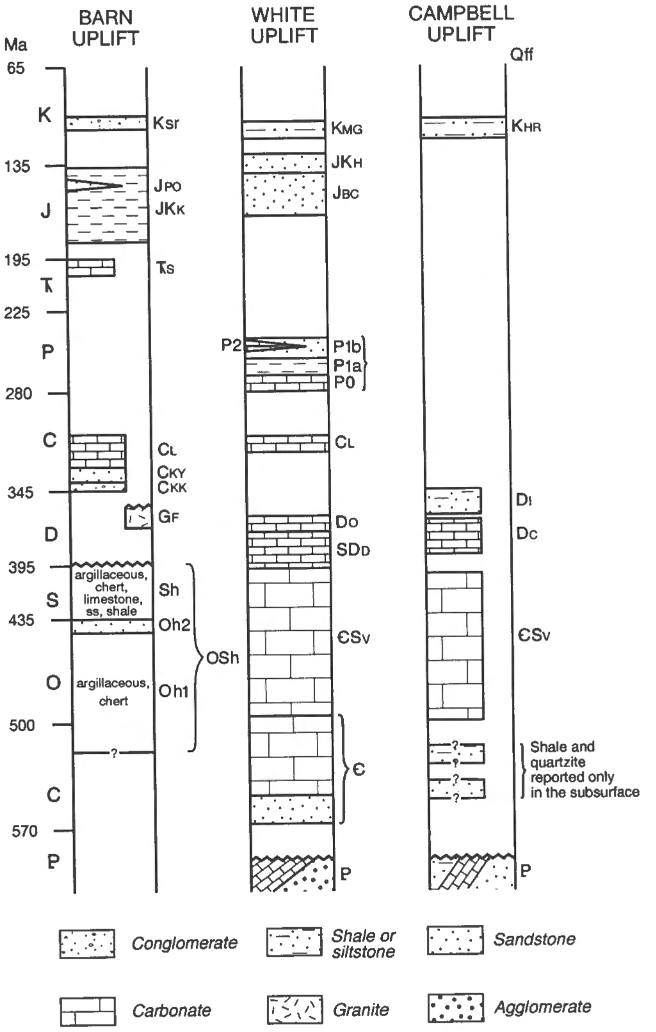


Figure 13.1. Major structural components of northern Yukon and adjacent District of Mackenzie. Barn, White, and Campbell uplifts are shown as shaded areas.



Ksr	"Skull Ridge" Unit	KMG	Mt. Goodenough Fm	€Sv	Vunta Fm
JPO	Porcupine Fm	JKH	Husky Fm	€	unnamed Cambrian units
JKK	Kingak Fm	JBC	Bug Creek Gp		
Ŧs	Shublik Fm	P2		Qff	unnamed Quaternary fluvial and apron deposits
CL	Lisburne Gp	P1b	Unnamed Permian units		
CKY	Kayak Fm	P1a			
CKK	Kekiktuk Fm	P0		KHR	Horton R. Fm
GF	Mt. Fitton Gr	DO	Ogilvie Fm	DI	Imperial Fm
OSh	Road River Fm	SDD	Kutchin Fm	DC	Cranswick Fm

Figure 13.2. *Columns showing stratigraphic units exposed in or adjacent to the three uplifts. Formation symbols apply to geologic maps. Disconformities exist where gaps occur between units, angular unconformities exist where zig-zag lines bound units.*

lithologic distribution is present. In three widely divergent directions from White Uplift, at distances of no more than 60 km, clastic sequences of similar age and thickness to the White Uplift carbonate core are found. Norford (1964) suggested that the uplift may occupy the site of a local carbonate accumulation. Other uplifts such as Cache Creek and Rat may be similarly coincident with local facies.

BARN UPLIFT

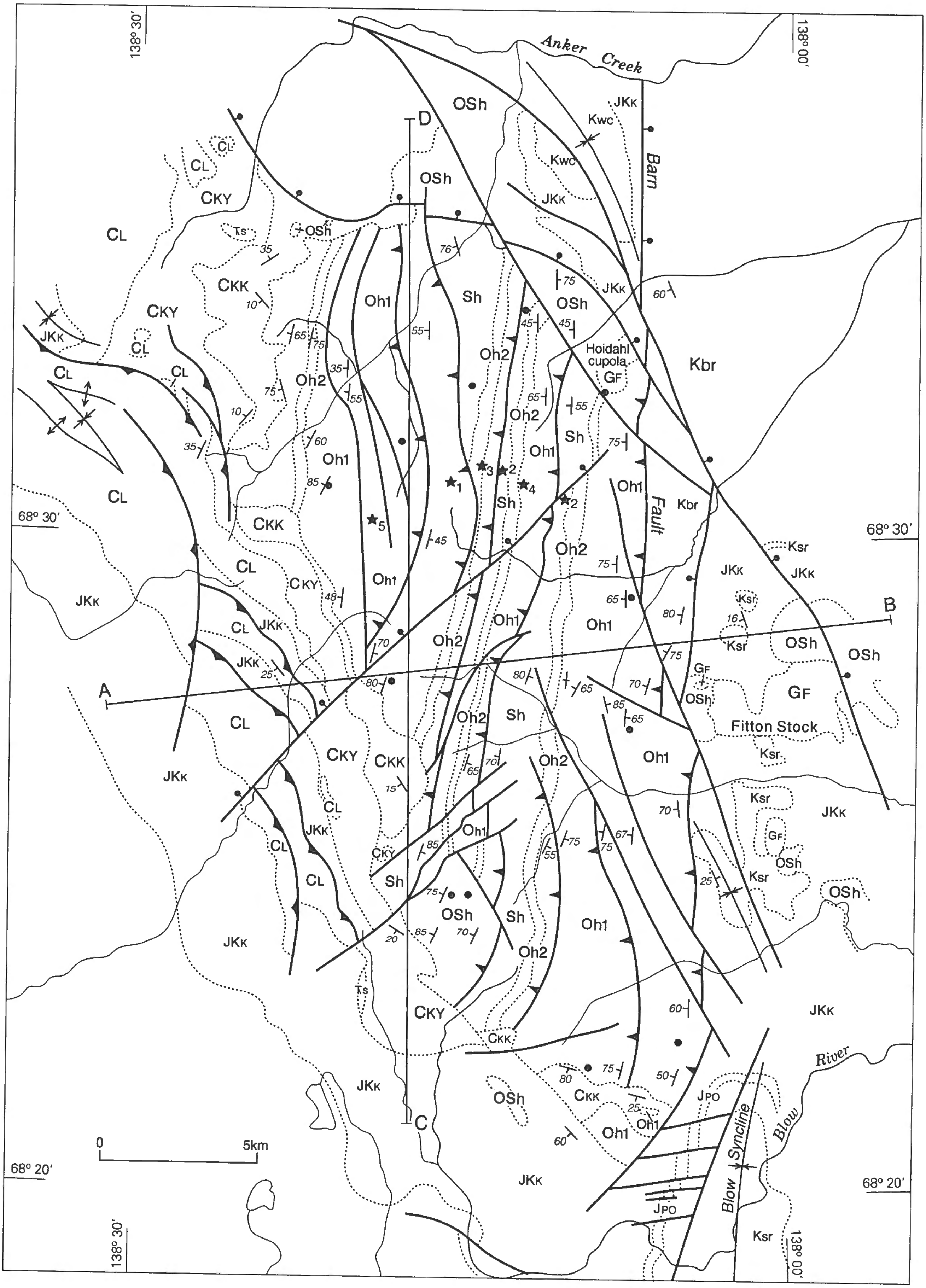
Introduction

Barn Uplift is an oval-shaped area of highly deformed Paleozoic, deep water, fine grained sediments measuring 25 by 12 km (Figs. 13.3, 13.4). These rocks define the exposed core, which is structurally asymmetric in east–west cross-section taking the flanks into account (Fig. 13.5). A sequence of Mississippian and younger clastic and carbonate rocks lies with structural conformity on the west side and dips away from the core. On the east side, the core is fault-bounded against Cretaceous and Jurassic clastics. It is areally the largest of the three uplifts and contains the most highly deformed and most structurally thickened core.

Stratigraphic framework

The core

At least 3000 m of chert and argillite interspersed with lesser amounts of quartzite and limestone comprise the core of Barn Uplift. Repetitions of strata by faults prevent the top and bottom of the core stratigraphic interval from being identified and introduces uncertainties in the estimated thickness. An upper limit to the age of the core succession is determined by the angular unconformity between it and the Mississippian Kekiktuk Formation. Several collections of graptolites have been made within the succession (Martin, 1959, p. 2414; Norford, 1964, p. 137; Norris, 1971, p. 106; Lenz and Perry, 1972, p. 1131) and indicate that deposition began at least in Early Arenigian (Early Ordovician). Furthermore, Cecile (1988) reports the trace fossil *Oldhamia*, which dates the core succession back to Early Cambrian time. The youngest age attributed to graptolites in the core is Ludlovian (Late Silurian) but Lenz and Perry (1972) suggest that the succession may extend into the Devonian based on plant impressions they have found. In a locality 30 km to the south of Barn Uplift, Lenz and Perry (1972) also found Lower Devonian graptolites in an inlier of shales that may be related to the core succession. If so, this narrows the gap to the Middle and Late Devonian during which internal deformation of the core sequence was taking place.


138° 30'
138° 00'
Anker Creek
Barn Fault
D
C
A
B
OSh
Oh1
Oh2
Sh
Kbr
JKK
Kwc
CL
CKY
CKK
Ts
GF
Ksr
JPO
Hoidahl cupola
Fitton Stock
Blow Syncline
Blow River
68° 30'
68° 20'
0
5km
1
2
3
4
5

BARN UPLIFT

Kbr	*Sandstone, conglomerate and shale; flyschoid(Albian)*
Ksr	*"Skull Ridge" Unit*
KWC	*Lower Cretaceous; undivided*
JKK	*Kingak Fm*
JPO	*Porcupine Fm*
ŦS	*Shublik Fm*
CL	*Lisburne Gp*
CKY	*Kayak Fm*
CKK	*Kekiktuk Fm*
GF	*Mt. Fitton Graben*
Sh Oh2 Oh1	*Road River Fm*

WHITE UPLIFT

KRR	*Rat River Fm*
KMG	*Mt. Goodenough Fm*
JKH	*Husky Fm*
JBC	*Bug Creek Gp*
P2 P1b P1a P0	*Unnamed Permian units*
DO	*Ogilvie Fm*
SDD	*Kutchin Fm*

CAMPBELL UPLIFT

Qf	*Fluviatile silt, sand and gravel*
Qff	*Unnamed Quaternary fluvial and apron deposits*
TK	*Tertiary-Cretaceous; undivided*
KHR	*Horton River Fm*
DI	*Imperial Fm*
DC	*Cranswick Fm*
ЄSV	*Vunta Fm*
Є	*Unnamed Cambrian units*
P	*Proterozoic*

Geological contact	⁓
Fault, vertical (defined, approximate)	—
Fault, vertical (solid circle indicates downthrough side)	—•—
Fault, vertical contraction dip< 45°	—▲—
Fault, vertical contraction dip> 45°	—▲—
Anticline axis	—↕—
Syncline axis	—✕—
Fracture fabric station	●
Fossil locality, see caption........................	5★
Bedding, top known (inclined,vertical)	✗ 75✗
Line of section	A ⊢—⊣ B

Figure 13.3. *Geological map of Barn Uplift. The legend applies to all maps in this chapter. See Figure 13.2 for identification of the units.*

A Middle Devonian or earlier age is also suggested for the core succession by radiometric dating of the Mount Fitton stock and Hoidahl cupola, outcropping on the east side of the uplift. Bell (1974, p. 26), Wanless et al. (1965, p. 22), and Baadsgaard et al. (1961, p. 459) give a range of ages from 265 ± 10 m.y. to 370 ± 16 m.y. derived from K-Ar determinations for these granitic intrusions. In view of the uncertainty due to unknown argon loss, the older end of the range is probably nearest the true age. Though precise contact relations are not observed, the age relationships indicate that the granites intrude the core succession. Contact metamorphic effects are most pronounced about the Hoidahl Cupola where slaty argillites and quartzites weather bright orange and a skarn exists containing pyrite and sphalerite; wolframite occurs in quartz veins farther away.

Several stratigraphic sections have been measured in the core succession but all begin and end at nondiagnostic positions within it. By the use of paleontologic control linked with mapped repetitions of lithologic sequences, it is possible to identify at least three fault-bounded panels and perhaps five. Recognition of these panels allows an estimate of minimum thicknesses to be made. The longest measured stratigraphic section covers about 2400 m of strata. A total of about 3000 m is present if the section is extended to the probable boundaries of the panel containing the section. A distinct succession of limestone, quartzite, and chert, followed again by limestone, allows part of the core succession to be mapped across the uplift. However, where this series cannot be identified, position in the stratigraphic column must be extrapolated on purely lithologic correlations. This is tenuous but suggests that an additional 1000 m might be present in the core.

The argillites form olive to brown weathering units up to 200 m thick. Chert is almost as common and forms units up to 300 m thick. Chert units are usually composed of beds 1 to 30 cm thick, but units locally contain highly resistant beds up to 5 m thick. Chert units commonly contain partly argillaceous intervals weathering to lighter, porcellaneous colours. These intervals usually grade into argillites. The presence of argillite indicates a basinal environment removed from, but under the influence of, a terrigenous sediment source.

The site was not free of coarse clastic input, as demonstrated by a few prominent intervals of interbedded sandstone and argillite. Sandstone beds are usually 1 to 10 cm thick but many can be up to 1 m thick and rarely up to several meters. They commonly show flute casts, suggesting deposition by turbidity

Figure 13.4. *Oblique air photograph (NAPL photo T13L–108) of Barn Uplift looking north. The core is identified by north-striking strata of the undivided* OSh *unit, repeated by high-angle contraction faults (barbed lines).*

currents. Microscopic examination reveals the composition to be virtually pure quartz in most cases, but some distinction between sandstone units can be made on the basis of sorting and composition. At least two types of sandstone are present: a well sorted, medium quartz sand with rare chert grains; and a medium to very fine quartz sand with sericitized feldspar grains comprising about 2 per cent of the rock. A varying source for the sand is indicated, perhaps changing from a direct fluvial contribution to beach sands reworked by longshore transport. These units are between 50 and 200 m thick and at least one can be traced the entire length of the core.

Carbonates make up the remaining component, occurring as a few units up to 100 m thick. Only two or three units of carbonate seem to be present, all bounded by chert or argillite. These can be distinguished from fault repeats by their relationship to other distinct units. Pale yellow weathering beds of limestone less than 10 cm thick are most common but pale orange dolomite does occur. The carbonates probably originated as oozes because of the abundance of animal tests. Sparry calcite occupies pore space but little recrystallization appears to have taken place. Individual beds of carbonate–clast conglomerate occur, the clasts being angular and up to gravel size. The only other possible intraformational conglomerates are rare occurrences of angular chert clasts in a chert grain or recrystallized calcite matrix. Of all the lithologies, carbonates seem to be the most discontinuous. These units are conspicuous on airphotos but any one cannot be traced more than halfway across the core along strike. Also, they do not always reappear in fault repetitions.

The lithologic character of the entire core succession can only be estimated because of sparse paleontological control and the possibility of missed fault or fold repetitions. The oldest part of the core succession continues to Middle Ordovician as a series of predominantly chert and argillite intervals. In the Upper Ordovician through Upper Silurian succession, much more variability in lithology is seen with sandstones and carbonates appearing. However, this upper division seems to be only about half as thick as the pre-Upper Ordovician succession.

The age determinations and the observed lithologies indicate that the rocks of Barn Uplift core are distinct from the very thick intervals of lithic sandstones, argillites and limestones, and a relative lack of chert, that characterize much of the Neruokpuk Formation in the British Mountains. The most characteristic feature of the core succession is the frequent alternation of ridge-forming chert intervals with recessive argillites and the predominance of these lithologies. The confusion between the two groups of rocks has been laid to rest by the observation of Cambrian carbonates and volcanics overlying Neruokpuk strata in British Mountains (Norris, 1976) and the discovery of graptolite-bearing argillites on the north flank of the British Mountains (Norris, 1976). There, argillites appear to be remnant, unconformity or fault-bounded by Precambrian Neruokpuk and Jurassic Kingak strata and assignable to the Road River Formation. Based on the demonstrated age of the core succession in Barn Mountains, the core strata are considered to be equivalent to the Road River Formation.

Regionally, the Road River Formation represents a basinal environment and in its thickest known section (estimated at 3100 m, true thickness obscured by faulting) is composed of an upper shale, chert, and carbonate member and a lower, dominantly argillaceous and limestone member (Norford, 1964). The upper member extends from Lower Ordovician to

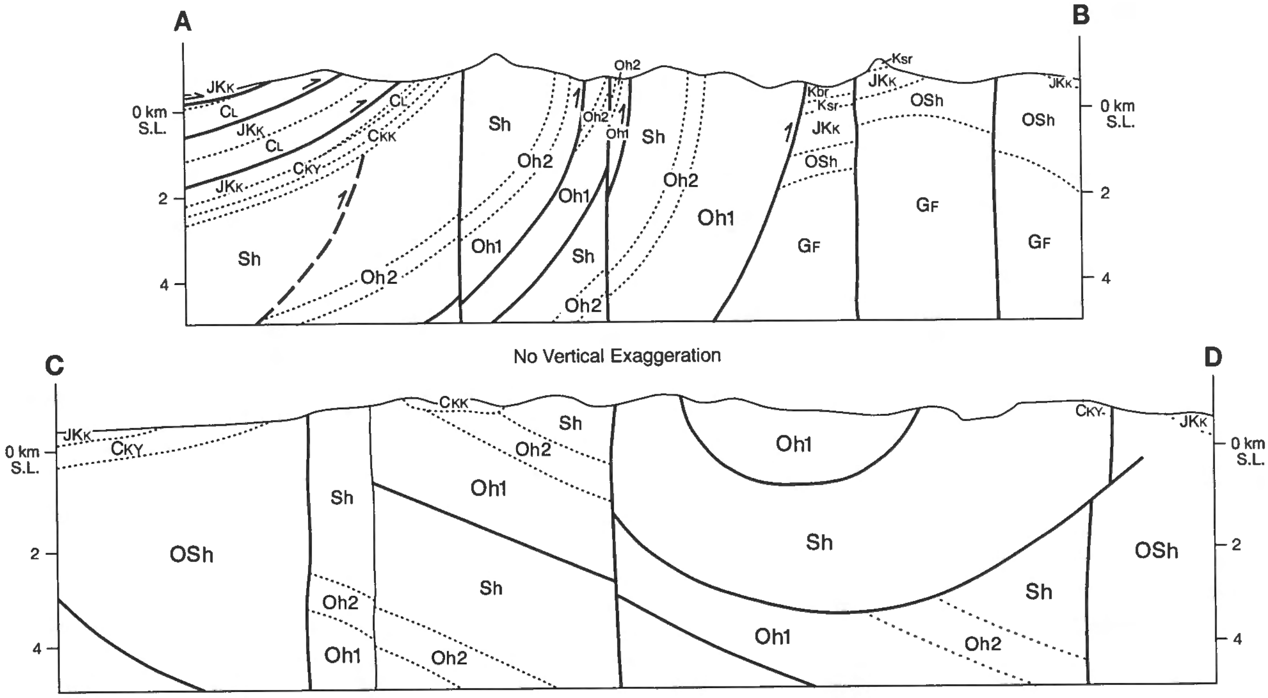


Figure 13.5. Geologic cross-sections of Barn Uplift. See Figure 13.3 for locations of the cross-sections. Horizontal and vertical scales are equal.

Upper Silurian and the thickest measured section is 1200 m in Richardson Mountains. It has carbonate shelf equivalents in White and Campbell uplifts. In Barn Uplift, only equivalents of the upper member seem to be represented but the apparent thickness there is much greater. Although the sandstone components account partly for this, in general, the Barn Uplift location may have been nearer a major source of terrigenous clastics than the locations represented by sections of the Road River Formation in the Ogilvie and Richardson Mountains.

The flanks

Rocks from uppermost Devonian or Mississippian to Jurassic lie with angular unconformity on rocks of the core succession on the west side of the uplift. The Mississippian Kekiktuk Formation is the oldest unit, with the possible exception of reported plant-bearing sandstones on the westernmost part of the core (Lenz and Perry, 1973). At Barn Uplift, the Kekiktuk Formation consists mainly of a chert and quartzite pebble conglomerate with rare thin quartzite intervals containing plant remains. The measured thickness ranges up to 80 m but the widest areas of outcrop on the west flank of the uplift suggest the thickness may reach twice this. Within 10 m stratigraphically of the core rocks, clast size increases to up to 0.5 m in diameter toward the contact. This increase points to some local derivation. The Kekiktuk Formation is absent locally through nondeposition, allowing strata of the Kayak and Kingak formations to be in contact with core rocks. The Kayak Formation overlies the Kekiktuk and is entirely Mississippian (Viséan) in age. It is a quartzite–shale sequence varying in measured thickness from 0 to 400 m. The formation is characterized by crossbedded quartzite intervals up to 10 m thick which locally pinch and swell over distances of about 200 m. These are interbedded with shale intervals up to 20 m thick containing coal seams 0.5 to 1 m thick. The Kayak Formation and Lisburne Group are both overstepped by shales of the Jurassic Kingak Formation. Along this unconformity are a few isolated exposures of carbonates and siltstones of the Triassic Shublik Formation.

On the east side, the core is fault-bounded but adjacent inliers of rock similar to the core succession are overlain by Kingak strata and a very thin Lower Cretaceous sandstone and shale sequence. These rocks are in turn overlain unconformably by a chert and quartzite pebble conglomerate succession containing interbeds of siltstone (chert conglomerate unit of Jeletzky, 1971; unit Ksr in Fig. 13.2). This conglomerate occurs as outliers along the east side of the core and has a maximum measured thickness of 150 m. Regionally, the conglomerate represents the base of the Aptian–Albian Flysch Division (Young, 1974) with local derivation from rocks of the core.

Structural components

The most obvious feature of Barn Uplift is its highly deformed core of lower Paleozoic strata. The unconformities between these rocks and the Kekiktuk, Kayak, and Kingak formations define the boundary of the core on the south and west sides. Steeply dipping or vertical faults form the boundary on the east (Barn Fault) and north. The most visible structural features are the uniform north strike and the general westward inclination of strata contained within fault-bounded panels. Inclination of bedding is seldom less than 60° (Fig. 13.6). Although the small amount of unobscured bedrock prevents the recognition of other structures, the paleontologic data confirms that repetition of stratigraphic sequences seen in measured sections are structural. These repeats are interpreted to be homoclinal panels bounded by contraction faults dipping steeply to the west. The most prominent quartzite unit of the core (unit Oh2, Fig. 13.3) is used as a marker and is thought to identify four major panels. There are probably a total of five panels and the eastern and westernmost of these appear to be subdivided by secondary reverse faults. Cecile (1988) mapped several isoclinal folds in the southeastern quadrant of the core. Some mesoscopic-scale isolated folding in chert has been noted but major folding in the core cannot be confidently documented.

Because of the strike parallelism of the markers, the major reverse faults are thought to be layer-parallel, or approximately so, at their present level of exposure. It is difficult to say what becomes of them beyond the core. The only other nearby large exposure of the core succession forms Hoidahl dome, an inlier about 10 km southeast of the core. This inlier of slaty argillite also displays a structural grain trending slightly east of north, suggesting that the fabric of the core is more widespread.

The uplift is structurally asymmetric with the greatest amount of structural relief on the east side (Fig. 13.4). If the present west to southwest dip of the sub-Kekiktuk unconformity is projected toward the east side of the core, at least 1000 m of differential uplift is indicated. Further constraint on the amount of uplift is difficult to determine because the amount of the core succession removed below the Mesozoic cover in the east side is unknown.

Figure 13.6. Ridge-level view of the west–central part of Barn Uplift core looking north. Chert intervals form spines and light-toned bands are carbonates. GSC photo KGS2436C.

Other inliers of core strata are immediately east of Barn Uplift. They are possibly overlain by the Aptian–Albian succession and seem to outline an eastern extension of Barn Uplift. This extension contains the largest outcrop area of Mount Fitton granite. The apparent depositional contact of Lower Cretaceous strata with the granite, and their relatively fine grained texture suggest that the contact is nonconformable and not steeply inclined. This implies that the granite occupies a much larger horizontal area at a shallow depth. Because core strata must also be present to host the intrusion, Barn Uplift may, strictly speaking, be the entire area containing Mount Fitton granite and nearby outliers of core strata, as well as the core.

The flanks of the core exhibit less severe horizontal shortening and only show a fault contact along part of the perimeter. The east side is bounded by a near-vertical, north-trending fault (Barn Fault) which is also the westernmost major fault, parallel to the group of faults known as the Rapid Fault Array (Yorath and Norris, 1975). At Barn Uplift, this fault coincides with the easternmost of the series of high-angle contraction faults occupying the core. A minimum vertical separation of approximately 300 m can be estimated based on the maximum elevation of exposure of core rocks relative to the elevation of the sub-Jurassic unconformity on the east flank. It is probable that the displacement is considerably more, but timing and magnitude are in doubt due to post-Jurassic erosion of the core.

Segments of other high-angle or vertical faults bound the north side of the core. Vertical movement is again demonstrated for these faults by the presence of the sub-Jurassic unconformity below the highest elevation of exposure of core rocks. These faults continue northwestward and merge with the fabric of Romanzof Uplift. Other structures that merge into Romanzof Uplift occupy a band along the west side of the core. These are open folds and low-angle contraction faults repeating Kingak and Lisburne strata on a decollement apparently in the Kayak Formation.

Stratigraphic hiatuses and omissions on the flanks of Barn Uplift indicate that more than one episode of deformation has contributed to the formation of this structure. The erosional truncation of the core structural fabric at the unconformity with the Kekiktuk Formation indicates that the first stage of deformation took place in the Middle or Late Devonian. This stage produced the contraction faults that structurally thicken the core succession. Together with the Middle Devonian intrusion of the Mount Fitton granite, these two events may be attributable to the Ellesmerian Orogeny. Apparent local derivation of some Kekiktuk strata at Barn Mountains suggests that uplift was concentrated at the site of the present core but the widespread unconformities beneath the Shublik and Kingak formations indicate that the entire Romanzof–Barn uplifts region was bevelled prior to Kingak deposition. This erosion occurred at different times between the Late Permian and Early Jurassic (D.K. Norris, pers. comm., 1989). A second stage of mild uplift, localized at the present site of the core, may have taken place before Kingak deposition because bevelling appears to have locally removed all strata below the Kingak Formation down to the core succession on the east flank of the core.

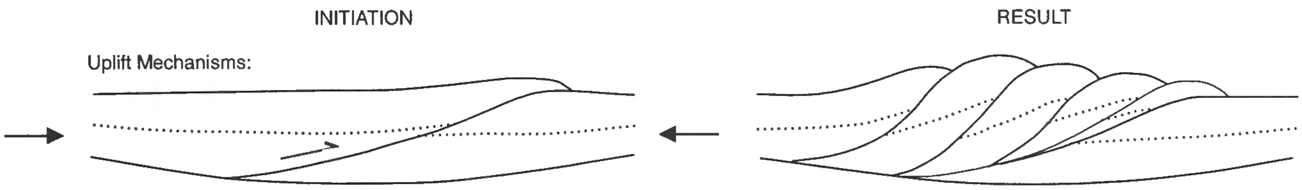
Most of the structural relief of the core is thought to have originated during a third event, an episode of horizontal compression in the Late Cretaceous. A stratigraphic hiatus indicating uplift in the latest Early Cretaceous is present on the eastward extension of the uplift centred about Mount Fitton Stock. Here, about 100 m of shale and siltstone is all that represents Lower Cretaceous deposition between the Kingak and the Aptian–Albian conglomerate. Blow Syncline, adjacent to the south end of the core, exposes a thickening section of Kingak. Continuing clockwise about the core, close to 1000 m of Lower Cretaceous sandstone and shale (Martin Creek, McGuire and Kamik formations; Dixon, 1982) appear on the southwest flank (Jeletzky, 1975), about 5 km southwest of the southernmost exposure of the core. The absence of these strata on the eastern extension suggests that uplift resulted in nondeposition. Uplift of the core is also suggested by steep dips of the Kingak and Kekiktuk formations away from the core on the west and south sides. It is apparent that the greatest amount of uplift was located on the east side of the core, considering that the upper Paleozoic units flanking the west side are not in fault contact with the core. That part of Barn Fault bounding the east side of the core probably accommodated most of this movement. Finally, the two sets of vertical, dip-slip faults arranged symmetrically on the east and west halves of the core appear to offset the core boundary (i.e., northwest- and northeast-trending faults in Fig. 13.3). They were probably formed along with faults cutting the Aptian–Albian conglomerate unit. Locally this conglomerate may have been shed from the core area and, in any event, has been subsequently tilted during the last episode of deformation.

Structural interpretation

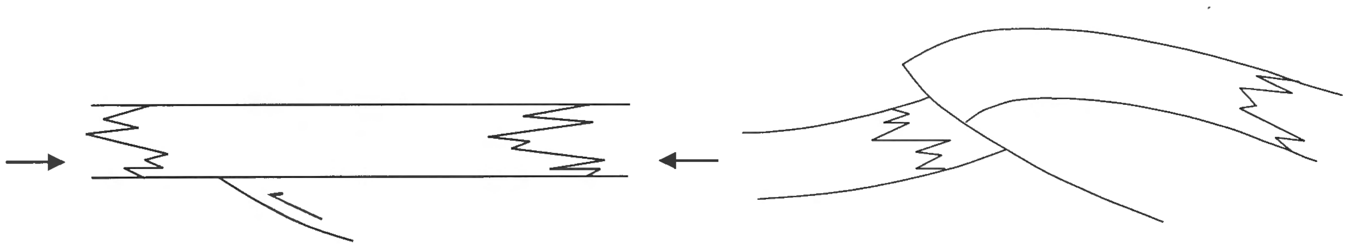
Barn Uplift has been produced by the tectonic thickening of an already abnormally thick equivalent of the Road River Formation. Movement along a closely spaced series of contraction faults is the dominant mechanism by which thickening has been achieved (Fig. 13.7). Cecile (1988) mapped folds in the southeast quadrant of the core but their existence elsewhere cannot be reconciled with fossil and lithologically-delineated fault panels. The style of deformation in the core is also displayed in the foothills belt of the eastern Canadian Cordillera. Large-scale folds are absent in both cases, perhaps due to the lack of thick, mechanically stiff units that would act as struts. Such mechanically dominant units would take a relatively large portion of a compressive load, yet remain confined such that failure by fracture was inhibited. All lithologic units in the core of Barn Uplift are well bedded with no lithology forming a single massive or mechanically dominant unit. Furthermore, a body of strata exhibiting local depositional thickening would tend to oppose folding due to a reduced aspect ratio at the site of the thickening.

The initial deformation was possibly caused by the formation of detachment surfaces parallel to the bedding. Continuing movement along a detachment would be accompanied by increasing compression. At some distance ahead of this moving element, a stationary element would eventually be encountered, providing a critical amount of resistance. At this point, the detachment would be forced to cut across the layering to continue. In the case of Barn Uplift, the impediment may have been Mount Fitton stock.

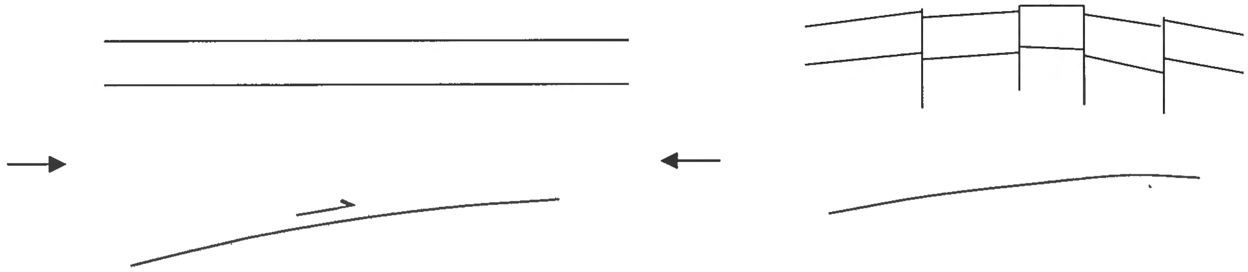
The structural development of the core requires a mechanism that produces a series of layer-parallel reverse faults bounding steeply inclined panels. One possibility would require the formation of an initial fault with a ramp of rapidly increasing inclination. The body of rock moving up this ramp would be forced to assume a steep inclination. Layer parallelism would then be favoured for new faults formed in this steepened area. However, this mechanism would require a large amount of work because considerable uplift would be required to introduce steeply inclined beds on each new fault. Alternatively, a single shallow ramp could form and localize successive, closely spaced splays in the wedge of the primary panel (Fig. 13.7). These splays would in turn be inclined at a shallow angle to the bedding and increasing resistance to forward motion would initiate successive new faults. A duplex structure would result. These mechanisms are kinematic hypotheses for achieving the observed structure. They merely exclude large-scale folding and



Elevation of a tectoniically thickened basinal sedimentary sequence: Barn Uplift



Elevation along a fault localized by a sedimentary facies change: White Uplift



Doming over the ramp of a deep contraction fault: Campbell Uplift

Figure 13.7. *Inferred initial geometric conditions and subsequent responses to compression for the three uplifts. The present core of Barn Uplift was formed by the elevation of part of the tectonically thickened unit shown in the diagram.*

faulting at high angles to the bedding, features which do not seem to be common in the uplift.

A synopsis of mesoscopic fracture fabric samples taken at several locations in the core reveals a preferred vertical orientation, striking about 105° (Fig. 13.8a). This fabric becomes obscured when each sample is rotated to bring the bedding attitude to horizontal (Fig. 13.8b). Therefore, its development may have taken place during the latter stages of deformation of the core. The coincidence of this fabric trend with a direction at right angles to the strike of the contraction faults suggests that this fabric element is an extension fracture set. If the core represents a portion of a mechanically thickened package of sediments, its continued deformation may have ultimately produced the extension fracture set. In this instance, the resistance of this package to continued compression would increase, causing it to sustain a high proportion of the overall east-west load. A theoretical study of compression of a viscous spherical body embedded in a less viscous medium (Shimamoto, 1975) indicates that a relaxation of stress occurs in the vicinity of the sphere, tangent to the load direction. Considering the core as a counterpart to the sphere, this relaxation would allow a simultaneous relaxation in the core at right angles to the east-west compression. The resulting extension in the core may have formed the east-west fracture set.

Most of the present structural relief of Barn Uplift is attributed to a subsequent period of deformation during the latest Cretaceous. At least one of the original high-angle contraction faults may have been reactiviated. However, the orientation of these north-striking faults relative to an inferred northeast-directed Laramide compression would presumably favour strike rather than dip movement on them. The family of northwest-trending faults bounding the north end of the uplift may have formed in response to the Laramide compression and served as the primary discontinuities along which the present structural relief

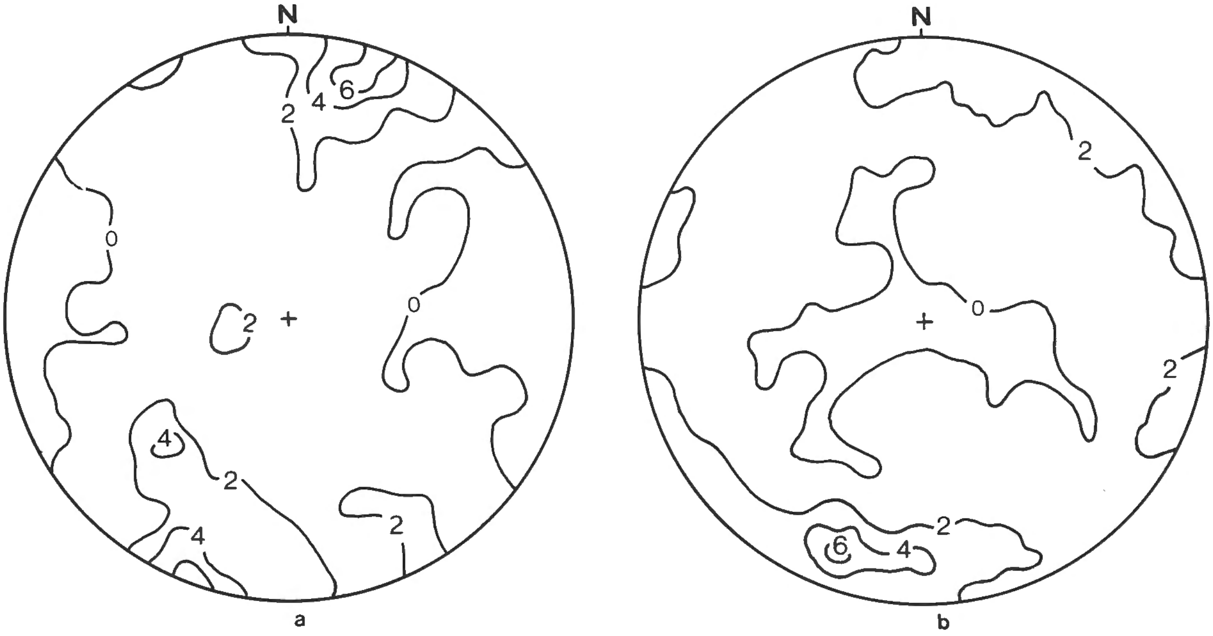


Figure 13.8. Contoured stereographic projections (lower hemisphere) of poles to 700 fractures from 14 localities in Barn Uplift core. Contours enclose areas containing greater than 0, 2, 4, and 6 per cent of the poles for each 1 per cent of the projection area. a) Fractures in natural orientation. b) Fractures with bedding rotated to the horizontal position.

was produced. In its tectonically thickened condition, the Road River succession may simply have been translated to the northeast, part of it also being elevated to form the present core. This translation was accommodated by mostly dip movement on the northwest-trending family and by mostly strike movement on the Barn Fault.

A northeast-directed compression is suggested by the northwest-trending group of thrust faults and folds on the west and southwest flank of the uplift. However, to the south the compression direction swings clockwise to the east to maintain compatibility with the north-trending Blow Syncline. On a regional scale, Barn Uplift is located on one limb of a major tectonic arc with Romanzof Uplift as its center. Norris (1972) accounted for this regional geometry by proposing a kinematic regime for the northern Canadian Cordillera. His model suggests that arcuate bundles of folds were formed by slippage of the Phanerozoic sedimentary veneer in response to widely spaced shearing couples. With increasing distance from an arc center, fold axes would tend to be rotated away from the compression directions. The change in fold orientation in the vicinity of Barn Uplift may be reflecting such a rotation. Certainly Barn Uplift is located in the area of transition from the northwest-trending fabric of Romanzof Uplift to the north-trending features of the Richardson Mountains.

WHITE UPLIFT

Introduction

White Uplift is located about 130 km southwest of Inuvik, N.W.T., in the northern Richardson Mountains. Aptly named, it comprises a rugged massif, roughly rectangular in plan, measuring 10 by 12 km and having a maximum topographic relief of 1000 m. Structurally, this feature is an uplifted and tilted block of light grey Paleozoic carbonate rocks bounded on all sides by dark brown clastic rocks of Permian and Jurassic age (Figs. 13.9, 13.11). This block is the core and is completely fault-bounded. It is the smallest of the three uplifts but shows the greatest demonstrable structural relief, 3500 m.

Stratigraphic framework

The core

Paleozoic limestone and dolomite together with a subordinate thickness of clastic and volcanic rocks of probable Precambrian age are exposed in the core of White Uplift (Dyke, 1972). The preserved stratigraphic thickness of the Paleozoic section is known from piecing together measured sections and is about 3000 m. Undoubtedly much additional Precambrian

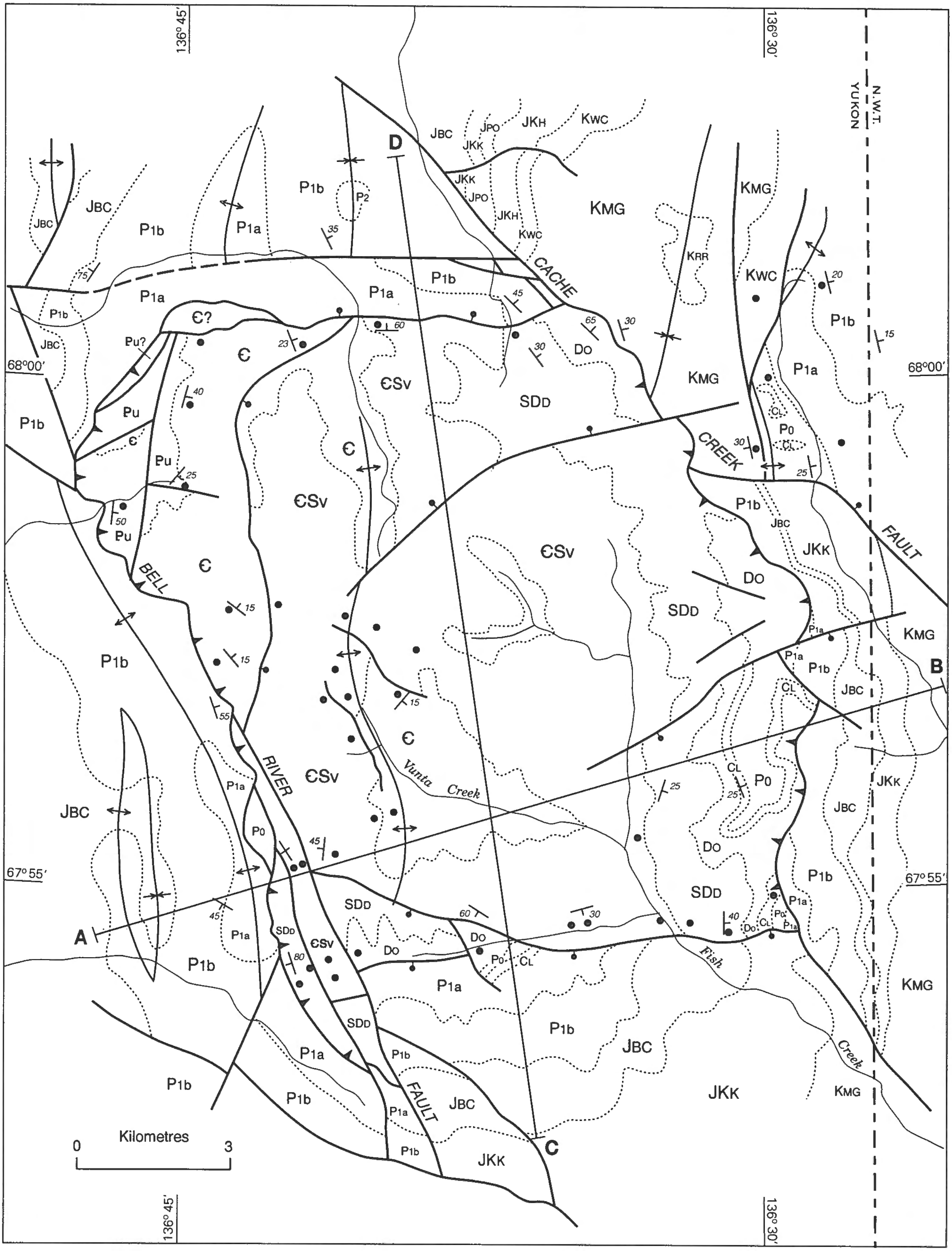


Figure 13.9. Geological map of White Uplift. See Figure 13.2 for identification of the units.

strata underlies it, if Campbell Uplift is analogous. The Precambrian is only exposed over a small area at the northwest corner of the core, with an apparent angular unconformity between it and the Paleozoic succession.

No complete stratigraphic section has been measured in the Precambrian of White Uplift. The lowest beds are massively bedded dolomite, overlain by a 100 m thick unit of dark green mafic volcanic and volcaniclastic rock. This volcanic unit is considered to be extrusive based on the presence of fine grained, laminated intervals interpreted as tuffs, and lenses of dolomite oriented parallel to the attitudes of the unit. Additional massively bedded dolomite and red to orange weathering quartzite complete the exposed sequence. It is the only exposure of Precambrian strata in the northern Richardson Mountains and as such illustrates the extreme structural relief of the uplift.

The base of the Paleozoic succession is represented by light grey quartzites, calcareous quartzite, and an interval of interbedded red shale and siltstone, all of Early Cambrian age (Fritz, 1974; Morrow, 1989). The unconformity at the base is not exposed but is apparently angular because of discordant bedding attitudes with Precambrian strata. Above the Lower Cambrian clastics is a carbonate sequence with all Paleozoic systems represented except the Mississippian.

A nearly complete section of the strata exposed in the core was studied by Norford (1964, Section 23) and Norris (1968, Section 116P7). Its base lies in the stratigraphically lowest exposure of Paleozoic rocks to be found in the center of the core. Fritz (1974) established the existence of Lower Cambrian rocks here, and there is about 300 m of unexposed strata between the fossil-bearing rocks and the Precambrian. About 800 m of thickly bedded, grey to orange weathering dolomite and dolomite breccia with minor limestone are thought to be included in the Cambrian. Above this lies the Vunta Formation (type section), 870 m of light grey pelletoidal to finely crystalline limestone. Only the upper part of the formation is fossiliferous, containing locally abundant brachiopod and coral debris dated as Late Silurian. The lowest beds are Lower Orodvician or Cambrian. The Vunta is the most resistant, cliff-forming unit in the carbonate sequence. It commonly weathers into massive towers and buttresses up to 30 m high, shapes suggestive of a biohermal or reefal origin.

Overlying the Vunta Formation are 740 m of siliceous dolomite and limestone, the top 550 m of which are assigned by Norris (1985) to the Kutchin Formation (type section). In a Section 6.7 km from the type section, in northeast White Uplift, this 740 m interval thickens to 990 m. Overlying the Kutchin Formation are 230 m of limestone assigned to the Ogilvie Formation. The Kutchin is relatively thin bedded and recessive, whereas the Ogilvie contains cliff-forming coralline and stromataporoidal beds. Together these formations range in age from Late Silurian to Middle Devonian and comprise the thickest accumulation of carbonates for this time interval in the northern Yukon. A disconformity separates 60 m of Pennsylvanian echinoderm-bryozoan limestone from the Ogilvie Formation (Bamber and Waterhouse, 1971). The core succession is capped with 45 m of Permian limestone disconformably overlying the Pennsylvanian.

The flanks

On the south and east flanks of the uplift, the Permian succession continues with about 740 m of shale, siltstone and some limestone beds (Section 116P5, equivalent to the "shale unit" of Bamber and Waterhouse, 1971). Pennsylvanian or Permian fossils in the carbonate inlier (unit Po) on the east flank (Fig. 13.9) suggest that few carbonate strata are missing from the top of the core section. The shale unit is overlain by 730 m of brownish grey to reddish brown weathering sandstone of the cliff-forming Permian "sandstone unit" (Bamber and Waterhouse, 1971). This Permian clastic succession forms most of the flanking strata for the uplift. Jurassic and Cretaceous strata are present only at the northeast corner.

The relationship between the lithologies and thicknesses exposed in White Uplift strata and the age-equivalent rocks in the surrounding area indicates that the uplift is at the site of a local, thick accumulation of carbonate rocks (Norford, 1964). A long lasting reef and lagoonal environment could account for such a localized buildup. Ordovician through Lower Devonian strata account for at least half of the carbonate thickness in White Uplift. Equivalent strata are represented by the clastic sequence of Barn Uplift core and Hoidahl Dome inlier, 40 to 50 km to the northwest. Noteworthy are exposures of the Road River Formation in northern Rat Uplift, 11 km southeast of White Uplift core. This proximity of contrasting strata indicates a rapid facies change in a direction roughly perpendicular to the trend of Aklavik Arch.

Although there is very little exposure of sub-Permian strata along the axis of Aklavik Arch in the vicinity of White Uplift, facies changes may exist and a thinning of the total carbonate succession probably does exist. Small inliers of sub-Permian rocks identified as Vunta Formation (Norris, 1981), located 12 and 30 km north-northeast of White Uplift, point to this thinning. A reef and lagoon environment may have been broken by channels connecting basins (i.e., between Richardson Trough and British-Barn Mountains Trough of Lenz, 1972). Also the Paleozoic carbonates exposed at Cambell Uplift (probably less than 1000 m) are much thinner than those at White Uplift (3000 m).

Stratigraphic omissions from the Jurassic and Lower Cretaceous in the immediate vicinity of White Uplift have been interpreted as early manifestations of the uplift. The general northwestward thickening of the Bug Creek Group is locally interrupted where the lower half of the formation is absent on Murray Ridge, 5 km east of the core (Poulton and Callomon, 1976; Poulton, 1978). White Uplift is also thought to have been manifested in Early Cretaceous time because of the absence of Lower Cretaceous strata (Kamik, McGuire, and Martin Creek formations) in a section about 2 km east of the southeast corner of the uplift (Jeletzky, 1975). No locally derived detritus has been found, as in the case of Barn Uplift, so perhaps this early expression of the uplift was subtle and only resulted in nondeposition. Cache Creek Uplift also was partially emergent at this time (Young et al., 1976) and White Uplift simply may have formed the southern end of a much larger positive area.

Structural framework

The most noteworthy feature of White Uplift is the great structural relief. The uplift is a completely fault-bounded block which has been raised, tilted, and internally deformed. At the northwest corner, Precambrian strata have been faulted against the Permian clastic sequence, giving about 3500 m of stratigraphic separation. Vertical displacements decrease eastward along the north and south bounding faults. On the east side of the core, Devonian strata are the oldest to have been uplifted against Permian, and at the southeast corner, the top of the carbonate succession (unit Po, Fig. 13.9) is exposed, giving a stratigraphic separation of probably less than 200 m. This variable displacement gives rise to an overall tilting of the core toward the east (Fig. 13.10).

The west side of the uplift is the most severely deformed. Superimposed on the overall tilting is asymmetric folding along a north-trending axis. Dips seldom exceed 30° on either limb until the slender, fault-bounded slice at the southwest corner is reached. In the slice, bedding is essentially vertical and adjacent

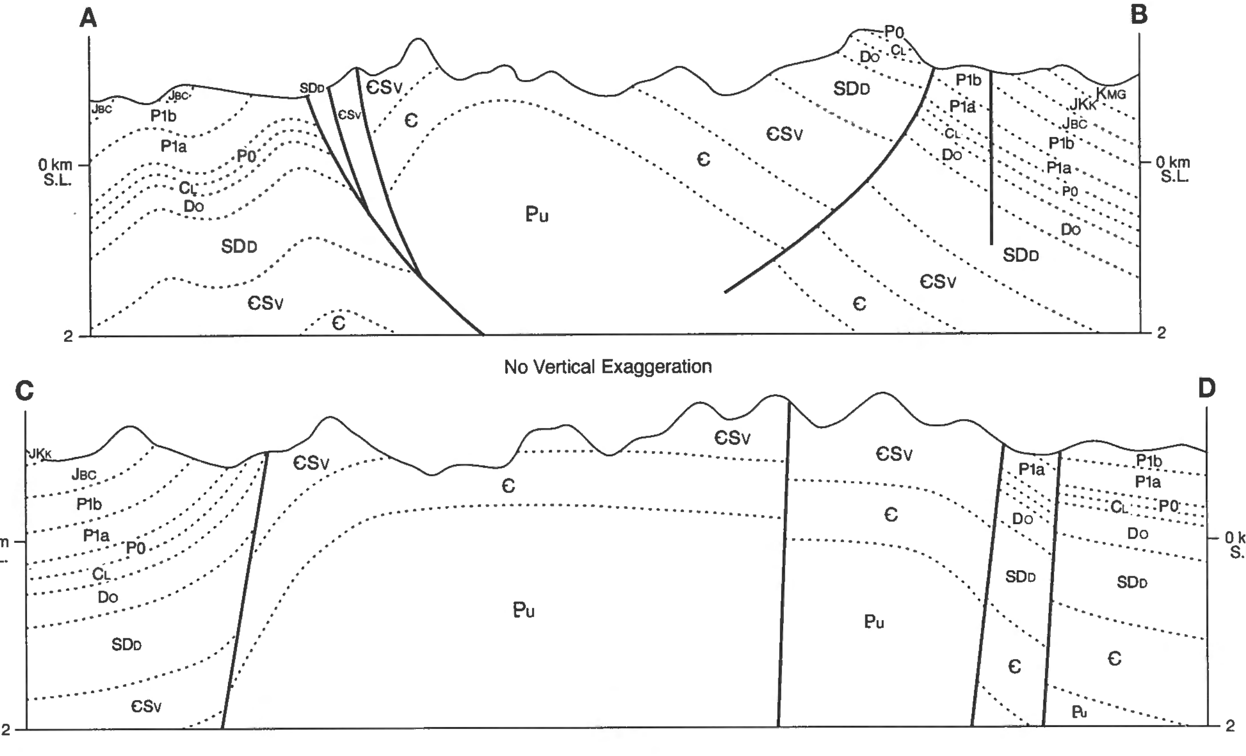


Figure 13.10. Geologic cross-sections of White Uplift. See Figure 13.9 for locations of the cross-sections. Horizontal and vertical scales are equal.

Figure 13.11. *Oblique air photograph (NAPL photo T3–27L) of White Uplift looking south. The core is bounded in part by Cache Creek and Bell River faults and comprises the light-toned, dissected massif in the right center portion of the photograph.*

to it, in the core, bedding dips up to 45° to the west. This degree of rotation is not present at the northwest corner. There, two thick fault slices containing Paleozoic strata show a gentle eastward dip. Adjacent to the north and south boundaries of the core, the Paleozoic strata are also inclined toward the bounding faults, although only obliquely at the north end, as stratigraphic separation increases considerably moving west.

The Bell River Fault bounds the west side of the core and is inclined steeply toward the core (Fig. 13.12). The Precambrain outcrop forms part of its hanging wall. Here the fault and bedding orientation in the Precambrian are within 20° of being parallel, suggesting that this fault may have begun as a bedding plane fault in Precambrian strata. Evidence for strike-slip displacement on it exists where a segment of the south-bounding fault and the Permian

Figure 13.12. Bell River Fault looking north where it separates the carbonate core of White Uplift from Permian clastics on the left. GSC photo KGS2436A.

carbonate–clastic contact have been left-laterally offset by approximately 2 km (Fig. 13.9). Therefore, the vertical carbonate slice was originally positioned more centrally along the west side of the core. The fault bounding the east side of the uplift also dips toward the core but probably has accomplished no more than 500 m of vertical displacement. Greater movement is apparent at the northeast corner, but Cache Creek Fault is coincident there and has added its own component of vertical movement. The faults bounding the north and south sides of the core are vertical. Several east-trending vertical faults showing minor vertical displacement cut the interior of the core. They may have helped to accommodate differential uplift.

The inclination of strata on the flanks of the uplift shows a varying relationship with the orientation of strata in the core. The south and east flanks dip away from the core at orientations similar to that of the adjacent core strata. The discordance is much more severe on the north flank where north-trending structures are truncated by a vertical fault, parallel to the north boundary. This fault appears to be part of a zone of deformation related to vertical movement on the north-bounding fault.

Samples of fracture fabric have been taken from two areas in the uplift. In both cases synoptic stereographic diagrams of poles to fractures have been made for each area with all data rotated to bring bedding to the horizontal position. Figure 13.13a is composed of five samples taken from the east flank and can be interpreted simply as indicating east–west compression. This assumes that the three most closely spaced concentrations of poles represent a conjugate shear fracture set and an extension fracture set. The concentration oriented at right angles to the extension set may be an extension set produced during a later stage in the process of uplift.

Evidence of east–west compression in the core is obscured by fractures that have formed due to local stresses accompanying uplift. Ten samples were taken from the least rotated part of the core and even here fractures show a complex distribution (Fig. 13.13b). The most general feature is the girdle of poles around the primitive circle. This girdle contains several concentrations, the most prominent of which identifies a set of north-trending, near-vertical fractures. Many of the fractures may have formed during extension when the doming of the core took place. The north-trending fracture concentration may reflect a relaxation of east–west compression as flexure about a dominantly north–south axis progressed. Other concentrations not in the main girdle may represent vertical fractures that formed after bedding began rotation.

Structural interpretation

The presence of north-trending folds and the fracture fabric shown in Figure 13.13a indicates that east–west compression operated in the vicinity of White Uplift. This compression produced reverse dip-slip movement along the east and west-bounding faults. Because these faults are inclined toward one another, movement on them resulted in uplift of the included block. The vertical faults on the north and south sides were passive to the extent that they accommodated the uplift occurring on the east and west faults. The position of the north and south faults may have been determined by facies changes in the Paleozoic sequence.

A considerable horizontal component of displacement is necessary on the Bell River Fault if deformation in the core is to maintain continuity with shortening expressed by folding in the clastic rocks north and south of the core. For this shortening to be accommodated on this fault, it must decrease in inclination with depth. The horizontal component of movement available if the fault continued steeply at depth would not be enough to satisfy this continuity requirement. Total shortening in the core appears to be roughly equal from north to south but is apportioned between the Bell River fault and the core anticline parallel to it. Adjacent to the northwest corner, there is no core fold and the greatest displacement on the Bell River Fault occurs. To the south, displacement decreases but the fold is present.

The carbonate slice which bounds the west limb of the anticline may have formed due to elongation of this limb. This would suggest that the fold was partly a forced feature rather than entirely a buckle. The forced part of the folding may have occurred as Paleozoic strata draped over a step formed in the Precambrian by the upward propagation of the Bell River Fault. Although little more than rigid body motion took place in the Precambrian strata at the northwest corner, it is evident from the large size of the core fold that deformation extended into the Precambrian strata in the core.

Experimental study

The formation of White Uplift may be linked to the localization of faulting by sedimentary facies changes. To study this hypothesis experimentally, rock

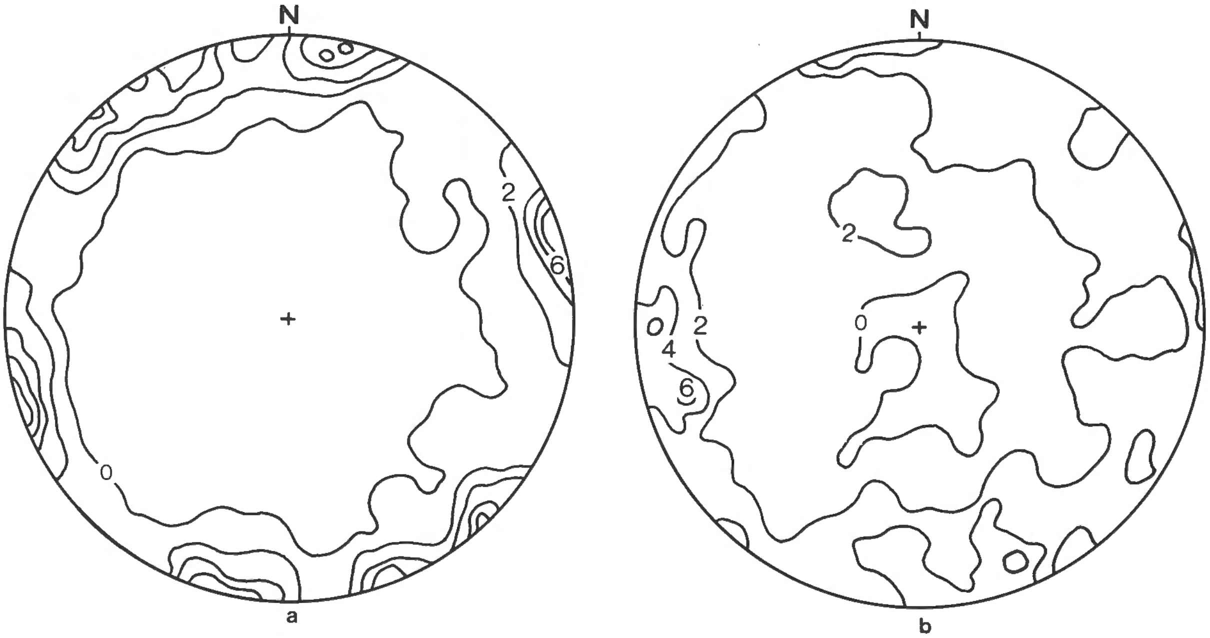


Figure 13.13. Contoured stereographic projections of poles to fractures for parts of White Uplift. Contours enclose areas containing greater than 0, 2, 4, 6, and 8 per cent of the poles for each 1 per cent of the projection area. a) 250 poles from five localities on the east flank, bedding rotated to the horizontal position. b) 500 poles from 10 localities in the center of the core, bedding rotated to the horizontal position.

specimens consisting of three sandstone layers — the central layer composed of two sandstone segments with a central limestone segment — were deformed in a triaxial compression apparatus (Dyke, 1976). The experiments were conducted under dry conditions, at room temperature, at an axial shortening rate of 10^{-4}/sec., and at confining pressures up to 300 Mpa.

At a confining pressure of 100 MPa, shortening to failure produces a single shear fracture in each outer layer (Fig. 13.14). Each fracture is located adjacent to the central limestone segment or inclusion and meets this inclusion distinctly inward from a corner, not opposite a corner. Microscopic examination of the outer layers reveals a concentration of microfractures centered over each end of the inclusion. Because of the relatively high ductility of the limestone, a disproportionately large part of the compression in the central layer is taken up by the inclusion (Fig. 13.14). This difference produces shear stresses along the contacts between the inclusion and outer layers. These shear stresses were included in the boundary conditions needed to solve for the elastic deformation of the inclusion (an elastic solution was considered appropriate in view of the small strains involved). The solution predicts that the ends of the inclusion shorten the most but undergo a corresponding thickening perpendicular to the shortening direction. The outer layers must conform to this new shape assumed by the inclusion, developing small forced folds over its thickened ends. The superposition of the compressive fibre stress in these folds on the load produced by the specimen end loading results in stress concentrations high enough to localize microfractures in the sand grains of the outer layers. With continued shortening, a shear fracture forms at the site of a microfracture concentration.

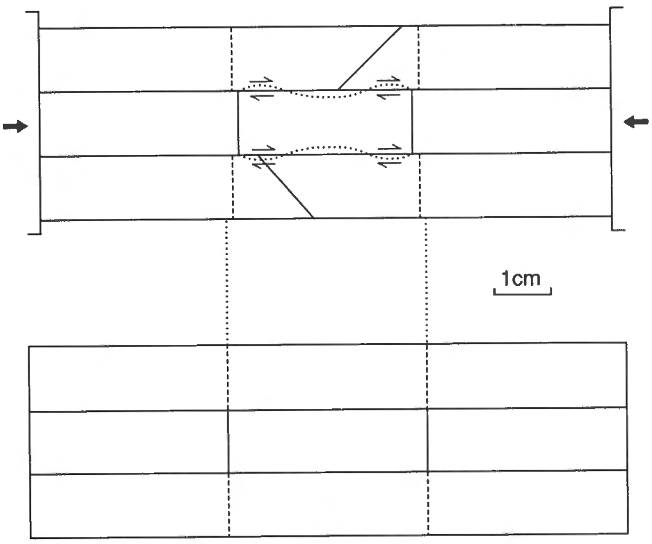


Figure 13.14. Cross-sections of the specimen used in the experimental study showing initial shape and deformation under end loading. Shortening in the central layer is taken up mostly by the inclusion, leading to the development of the depicted shear couples between layers. The resulting deformation of the inclusion as shown by dotted lines is exaggerated but produces forced folds in the outer layers and ultimately shear failure.

Direct surface measurements made on an inclusion confirm the theoretically predicted strain parallel to the loading direction. To verify the importance of a shear stress between the inclusion and the outer layers, tests were conducted with these contacts lubricated to reduce the shear stress. Corner stress concentrations became influential in localizing fractures and the load required to produce shear fractures increased 20 per cent. The shear stresses are a necessary boundary condition for producing the forced folding. Without this forced folding, microfracture concentrations are not available to initiate shear fractures and an entire outer layer must fail simultaneously, resulting in an increased load required for failure.

The experiments suggest a mechanism by which shear fractures can be localized at sites of lateral mechanical contrast. A sharp vertical boundary between lithologies is not necessary for this mechanism to operate. The shear stresses that act to localize the inception of a shear fracture arise because of a lateral difference in ductility. This would still be available in a gradational facies change of the abruptness that is probably associated with White Uplift. The structural relief present at White Uplift may be the result of movement along faults that were initiated by the influence of a lateral mechanical contrast on the local stress distribution (Fig. 13.7). This mechanism of fault localization accounts for the fundamental difference in structural style between White Uplift and Barn and Campbell uplifts.

CAMPBELL UPLIFT

Introduction

Campbell Uplift is centred about 15 km south of Inuvik, N.W.T. Most of the bedrock exposure occupies an oval shaped area, roughly 22 km long and 11 km wide, elongated in a northeast direction (Figs. 13.15, 13.17). The area is situated between the East Channel of the Mackenzie River and Campbell Lake, and forms a slightly elevated terrain broken by numerous cliffs. The uplift probably occupies a larger area than exposed but the southwestward continuation disappears beneath the fluvial veneer of the Mackenzie

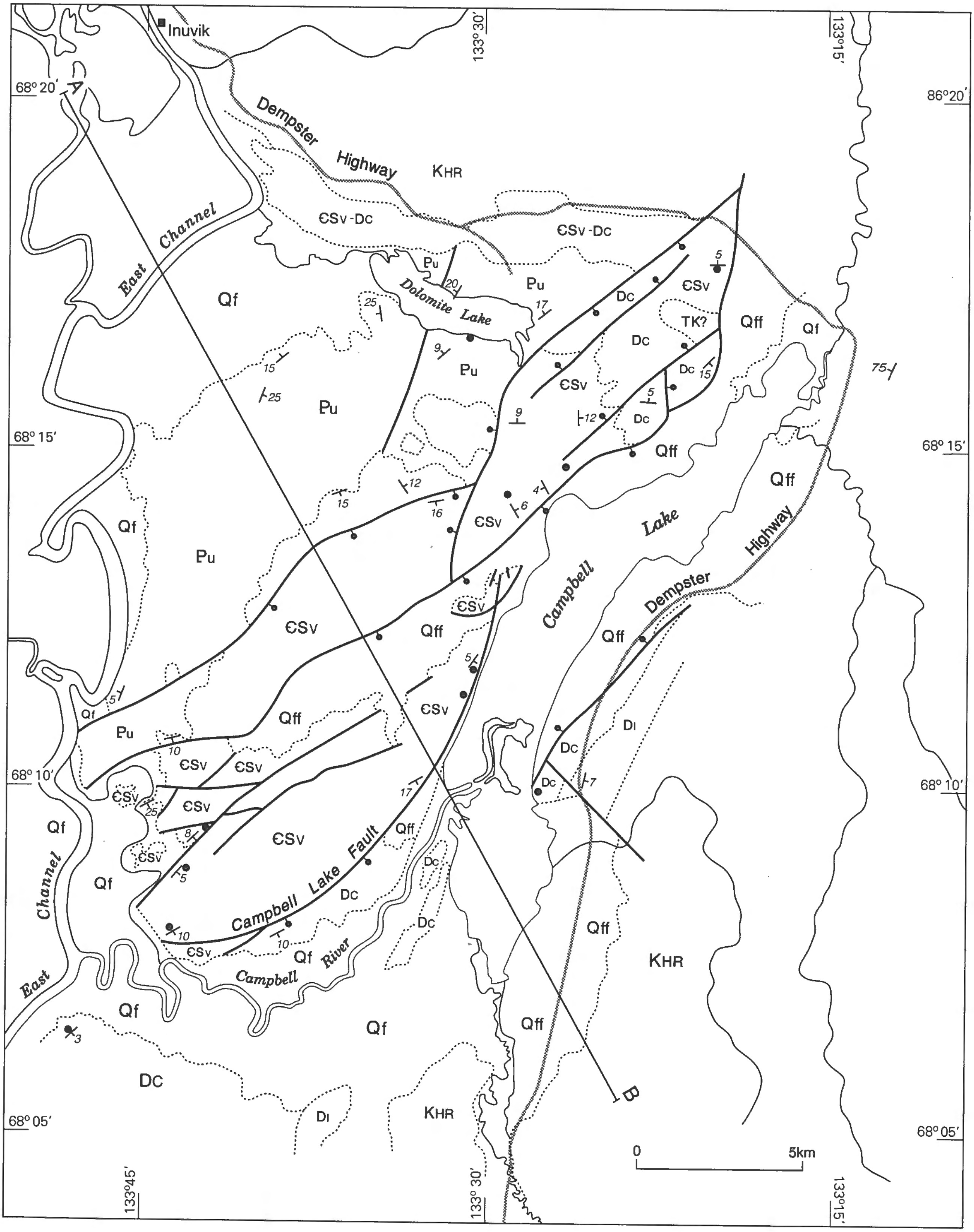


Figure 13.15. Geological map of Campbell Uplift. See Figure 13.2 for identification of the units.

Delta. Therefore its limits are somewhat arbitrarily defined by the edges of the Cretaceous or younger cover that overstep the central older rocks on all sides. Outliers to the southwest in the Mackenzie Delta extend the uplift in that direction. Drumlin-like ridges are responsible for a prominent set of south to southeast-trending lineations visible on the Vunta Formation in Figure 13.17.

The uplift is most likely a surface expression of a more extensive regional high, the northeast-trending Aklavik Arch Complex (Yorath and Norris, 1975). Though not of the abruptness of Barn or White Uplift, the structural relief expressed in Campbell Uplift is notable in view of the little deformed or undeformed character of the crestal and flanking rocks.

Stratigraphic setting

Campbell Uplift, and the structural trend on which it lies, separates the Mesozoic clastic accumulation of the lower Mackenzie Delta and Kugaluk Homocline from a predominantly Paleozoic carbonate and clastic succession to the southeast. The uplift exposes the Paleozoic carbonates which occur in the subsurface to the southeast and probably to the northwest. Mesozoic clastics occur to the southeast in Sitidgi Syncline, but are not as thick as those north of the uplift.

The oldest exposed rocks have been dated by paleomagnetism as 1.1 Ga (late Precambrian) (Norris and Black, 1964). Examination of the best exposures, together with airphoto interpretation, yields a very tentative lithological succession as follows: light orange-grey, massively bedded dolomite, commonly argillaceous to silty; dark red and olive slaty argillite; dark green to brown silty argillite; olive to dark brown sandstone; and light grey to reddish brown quartzite. The grain size of the carbonate portions is usually less than 1 mm and is commonly microcrystalline. This succession accounts for about 600 m of strata. However, deep seismic reflection data indicate that presumed Proterozoic rocks extend to a depth of 17 km beneath Campbell Uplift (Cook et al., 1987).

The Proterozoic rocks are overlain by massive-bedded dolomite. Although the contact is not exposed, the contrast in degree of deformation between the commonly steeply dipping Proterozoic rocks and the nearly flat lying carbonates precludes a conformable contact. The unconformity is readily mapped on airphotos where dolomites form an irregular boundary with the area underlain by Proterozoic strata. This contact is easily distinguished from curvilinear fault traces. No complete section of the lower Paleozoic carbonates is exposed but examination of records from the Amoco et al. Inuvik D-54 borehole, located 3 km northwest of Inuvik, shows approximately 750 m of dolomite overlying shales and quartzite. The clastic interval may represent the Lower Cambrian Old Fort Island Formation (Norris and Calverley, 1978), the remaining dolomite being one estimate for the thickness of Paleozoic carbonates at Campbell Uplift.

Determining the relative ages of the lower Paleozoic carbonates in the numerous fault blocks composing the uplift is hindered by a lack of precise paleontological dates and differing lithologies. Two lithostratigraphic divisions can be made. The lower of the two consists of coarsely crystalline, light greyish orange dolomite, locally containing laminated, algal mound-like structures. Overlying this are mostly dark grey, finely crystalline dolomites followed by predominantly light to medium grey, coarsely crystalline, relatively resistant dolomites. These dolomites form the largest area of outcrop in the uplift and extend beneath younger Paleozoic carbonates to the northeast and southwest. Fossils indicate Silurian to possibly Ordovician ages. Given an average southeastward dip of 5° to 10° for the sub-Paleozoic unconformity and Paleozoic strata, between 500 and 1000 m of this strata could be

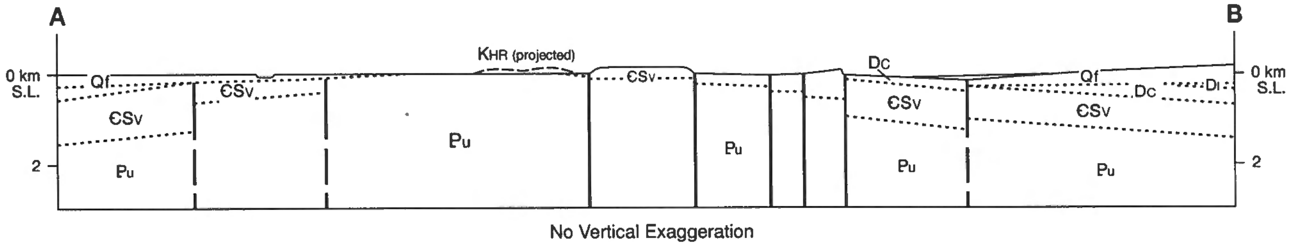


Figure 13.16. Geological cross-section of Campbell Uplift. See Figure 13.15 for location of the cross-section. Horizontal and vertical scales are equal.

Figure 13.17. *Oblique air photograph (NAPL photo A5023–33R) of Campbell Uplift looking northeast, showing exposures of Precambrian* (Pu) *and Paleozoic* (€Sv) *strata comprising the core.*

accommodated between the Precambrian and the present surface of carbonate exposure along the west shore of Campbell Lake. Faulting successively downdrops blocks from the Precambrian exposure to the lake, but the offsets of the unconformity are small, indicating that faulting probably adds little to the thickenss estimates. Therefore, this serves as a minimum thickness estimate for the pre-Devonian Paleozoic strata.

The closest exposed counterpart of this carbonate succession occurs at White Uplift, 130 km to the southwest. There, the Vunta Formation (870 m thick) ranges in age from Early Ordovician to Late Silurian, and Cambrian sub-Vunta carbonate strata have been identified. Dolomite intersected in the Richfield et al. Point Separation No. 1 well (located at the head of Mackenzie Delta), which lies beneath Early Devonian strata, is also correlated with the Vunta Formation (Tassonyi, 1969).

Early to Middle Devonian carbonates outcrop between Dolomite and Campbell lakes, along the east shore of Campbell Lake, and form outliers at the southwest end of the uplift. Norris (1985) has abandoned the previous assignment of these rocks to Ogilvie and Gossage formations and has instead assigned all Devonian carbonate strata in Campbell Uplift to the Cranswick Formation. These rocks consist of 0.5 m or thicker, medium to light grey weathering beds of finely crystalline dolomite and limestone overlain by more thin bedded, medium brownish grey to greyish orange carbonates. Exposures of limestone assigned to the lower part of the

Cranswick Formation occur in a quarry at the northeast end of the uplift and lie immediately beneath Cretaceous shales. There, macrofossils and conodont assemblages permit refinement of dating to late Early Devonian (Norris and Calverley, 1978).

Upper Devonian Imperial Formation is not known to outcrop on top of the uplift but appears to exist as an erosionally thinned wedge on the east flank. In a quarry lying immediately upsection from the outlier of Middle Devonian carbonates on the east side of Campbell Lake, interbedded siltstones and laminated shales contain palynomorphs giving a pre-Carboniferous, probably late Devonian, age (D.K. Norris, pers. comm., 1989). The location of this occurrence between Middle Devonian carbonates and the strike projection of Aptian-Albian rocks of similar appearance point to an interval of Imperial Formation that has thinned dramatically from the 1500 m of Imperial Formation present in the Point Separation well. The Imperial Formation has been locally removed where Cretaceous shales rest directly on the Proterozoic in the center of the uplift.

The complete blanketing of the uplift with Cretaceous strata is confirmed by the presence of black shale of the Horton River Formation near the crest of the uplift (Dyke, 1975). The shale contains a well-preserved foraminiferal assemblage of late Early Albian age (T.P. Chamney, pers. comm., 1974). This material lies with angular unconformity on Precambrian strata and probably overlapped the sub-Paleozoic unconformity. Before deposition of the Cretaceous strata, peneplanation of the uplift must have been essentially complete since no textural coarsening is seen in the overlying rocks. Infilling of a karst topography in the Cranswick Formation by this shale is seen in the above-mentioned quarry (Fig. 13.18), and shale of slightly younger age is seen in another quarry immediately north of the road connecting Inuvik with the airport (Norris and Calverley, 1978). On the southeast flank, shale and interbedded siltstone and sandstone containing load casts occur along Caribou Creek, which drains northward into the south end of Campbell Lake. These rocks are dated as Aptian-Albian and the load casts show current flow in an average direction of 230°, parallel to Aklavik Arch. Possible Tertiary sands and silts unconformably overlie the Cretaceous rocks along the creek.

Structural framework

Campbell Uplift is not a fault-bounded structure in the fashion of White and Barn uplifts. Rather it is an elongated dome cut by numerous northeast trending vertical faults and represents a broad culmination of Aklavik Arch. The Paleozoic succession dips away on all sides at a shallow angle, though probably more abruptly to the northwest and southeast than along the trend of the arch. Proterozoic rocks immediately below the sub-Paleozoic unconformity are exposed in cliffs and a quarry on the north side of Dolomite Lake. This unconformity is also encountered at a depth of 1400 m in the Inuvik D-54 borehole. If this unconformity extends as an unbroken surface to the well, a dip of about 8° would be required, indicating a flank of roughly equal inclination to that in the southeast. The uplift must plunge gently to the southwest because Devonian carbonate outliers are present as much as 20 km southwest from the nearest exposure of Vunta Formation.

Figure 13.18. *Paleo-karst opening developed in Devonian carbonates exposed in a quarry 20 km east of Inuvik on the Dempster Highway. The opening is filled with carbonate debris and shale of the Horton River Formation. GSC photo KGS2436B.*

The Proterozoic strata display the most severe deformation. Mesoscopic kink-folding in the thin bedded argillite is accompanied by folding on a larger scale around north and northeast-trending axes. This deformation is most certainly pre-Ordovician and probably Precambrian. Tectonism related to the Late Devonian Ellesmerian orogeny in the northern Yukon (Norris, 1973) was possibly responsible for the uplift and bevelling of the rocks at the sub-Cretaceous unconformity. Evidence for renewed activity during the Laramide orogeny is documented by the sub-Tertiary unconformity. Consequently, the uplift may be a Paleozoic feature that was rejuvenated during the Laramide.

All Phanerozoic strata show shallow dips, generally less than 10°. The Paleozoic and Proterozoic successions are cut by several vertical faults showing dip-slip offset. These faults divide the carbonates into several blocks, most of which have nearly constant bedding orientations (Fig. 13.16). Although individual faults are curvilinear, a general northeastward trend is apparent. These faults in general drop the Paleozoic strata so that progressively younger strata are encountered in the fault blocks southeastward from the Proterozoic core. Though detailed stratigraphic control is unavailable, the fault blocks appear to have an average dip-slip separation of 150 to 300 m. Collectively, the total structural relief they produced probably amounts to 900 to 1500 m; doming may have increased this relief. The downdropping appears to be reversed by the fault bounding the Devonian exposure on the east shore of Campbell Lake to form the Sitidgi Graben. The graben is probably floored with Cretaceous rocks. Gentle folding around northeast-trending axes is present in the Cretaceous rocks exposed on the southeast flank of the uplift. A synoptic stereographic plot of fracture fabric samples from the carbonate rocks (Fig. 13.19) shows a single pronounced concentration parallel to the northeast-trending faults. While individual samples show conjugate sets, the predominance of one set suggests that many of the fractures formed in an extensional state of stress.

Structural development

There is no obvious relationship between facies changes and subsequent deformation as seen at White Uplift. The structural grain of Campbell Uplift does parallel major faults inferred to extend northeastward from Aklavik Range (Treeless Creek and Eskimo Lakes faults; Norris, 1980). Movement on these was doubtless a reaction to a regional stress regime and Campbell Uplift probably responded to the same influence. The result was additional structural relief superimposed on a previously existing broad dome existing in Late Paleozoic time in the Paleozoic strata.

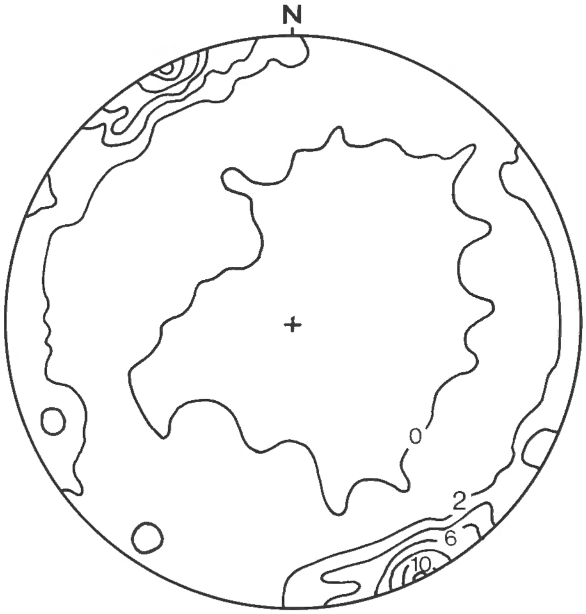


Figure 13.19. *Contoured stereographic projection of 800 poles to fractures from 16 localities in the Paleozoic rocks of Campbell Uplift. The bedding is rotated to the horizontal position. Contours enclose areas containing more than 0, 2, 4, 6, 8, 10, and 12 per cent of the poles for each 1 per cent of the projection area.*

Examination of deep seismic reflection records (Cook et al., 1987) indicates a major contraction fault within the Proterozoic interval beneath Campbell Uplift. A kinematic interpretation of these data shows a wedge of Proterozoic material driven from the northwest to initiate a duplex structure. The shortening at depth would be accompanied by uplift along one or more ramps of the duplex. The crest of this uplift would occupy the veneer of Paleozoic rocks and produce the doming that is Campbell Uplift. Furthermore, this doming would place these rocks in extension (Fig. 13.7), possibly giving rise to the northeast-trending array of faults cutting the uplift.

It is not clear whether Cretaceous rocks overstep any faults of the northeast array. If they do, support that the uplift originated as an Ellesmerian event would be demonstrated. This would also follow from the very probable overstepping of the sub-Paleozoic unconformity. Folding in the flanking Cretaceous rocks attests to subsequent, probable Laramide, activity. Fracture fabric in these rocks shows strong preferred orientations but not in the direction shown by the Paleozoic rocks.

SUMMARY

Multiple phases of deformation and complex facies distributions are typical of the northern Canadian Cordillera. Barn, White, and Campbell uplifts are all responses of laterally changing sedimentary geometries to these deformations. The link between sedimentary geometry and deformation is most easily demonstrated at White Uplift because of the coincidence of the uplift with a local carbonate facies. Mechanical properties, contrasting laterally across the facies change, have localized faults, and displacement on these faults has produced the uplift. Barn Uplift has been produced by the tectonic thickening of an already abnormally thick basin sequence. Uplift occurred in at least two major stages, the tectonic thickening being the first with subsequent uplift of this tectonic unit causing the present feature. Campbell Uplift is the least abrupt of the three and is not related to any Phanerozoic sedimentary distribution. It may be related to a more deeply seated horizontal shortening localized by a thickness change in the Proterozoic. Vertical movement in response to this shortening produced Campbell Uplift. In summary, though the three uplifts differ greatly in style and structural relief, all three appear to have resulted from horizontal compression. Their structural relief may depend on the abruptness of heterogeneities in the original sedimentary package or heterogeneities produced by earlier tectonic thickening.

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CHAPTER 14

PETROLOGY OF THE NORTHERN YUKON INTRUSIVE SUITE

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Burwash, R.A., 1996. Petrology of the Northern Yukon Intrusive Suite. In The Geology, Mineral and Hydrocarbon Potential of Northern Yukon Territory and Northwestern District of Mackenzie, Geological Survey of Canada, Bulletin 422, p. 359–367.

Abstract

The intrusive rocks of northern Yukon, excepting the Dave Lord pluton, belong to a late orogenic granite-granodiorite association. The Sr^{87}/SR^{86} initial ratios imply magma generation by anatexis of either a sedimentary wedge or older crystalline basement. The nepheline-normative rocks of Dave Lord pluton crystallized from a magma which would typically be generated in the mantle and emplaced into a rigid plate during crustal extension.

Geochronologic data are not sufficiently precise to establish the relative ages of the plutons. If all are essentially coeval, juxtaposition of different tectonic environments is implied. Alternatively, a spread of 80 million years (431–352 Ma) allows time for intrusion of synkinematic and late-kinematic granites followed by the post-kinematic Dave Lord syenite body.

Résumé

Les roches intrusives du nord du Yukon, à l'exception du pluton de Dave Lord, appartiennent à une association orogénique tardive de granite-granodiorite. Les rapports initiaux de Sr^{87}/Sr^{86} indiquent que le magma s'est formé par anatexie d'un biseau sédimentaire ou d'un socle cristallin plus ancien. Les roches à néphéline normative du pluton de Dave Lord ont cristallisé à partir d'un magma qui aurait typiquement été formé dans le manteau et mis en place dans une plaque rigide durant l'expansion de la croûte.

Les données géochronologiques ne sont pas suffisamment précises pour déterminer les âges relatifs des plutons. S'ils sont tous essentiellement contemporains, la juxtaposition des différents milieux tectoniques est possible. Par contre, un intervalle de 80 millions d'années (431–352 Ma) est suffisamment long pour permettre l'intrusion de granites syncinématiques et tardicinématiques avant celle du massif de syénite postcinématique de Dave Lord.

INTRODUCTION

A reconnaisance study of the petrology and geochemistry of the intrusive rocks of northern Yukon was undertaken using samples from both Operation Porcupine and the collections of the University of Alberta. For most samples, only a thin section and its matching off-cut were available, placing limits on the procedures that could be undertaken. Field data were also sparse, usually limited to the name of the pluton and the geographic coordinates of the sample (Fig. 14.1). The intrusive relationships between several of the plutons and mapped stratigraphic units are presented schematically on GSC Maps 1516A and 1518A, compiled by Norris (1981a, b). Information about the internal structural relationships of plutons would help to establish the number and sequence of intrusive phases, but little is available.

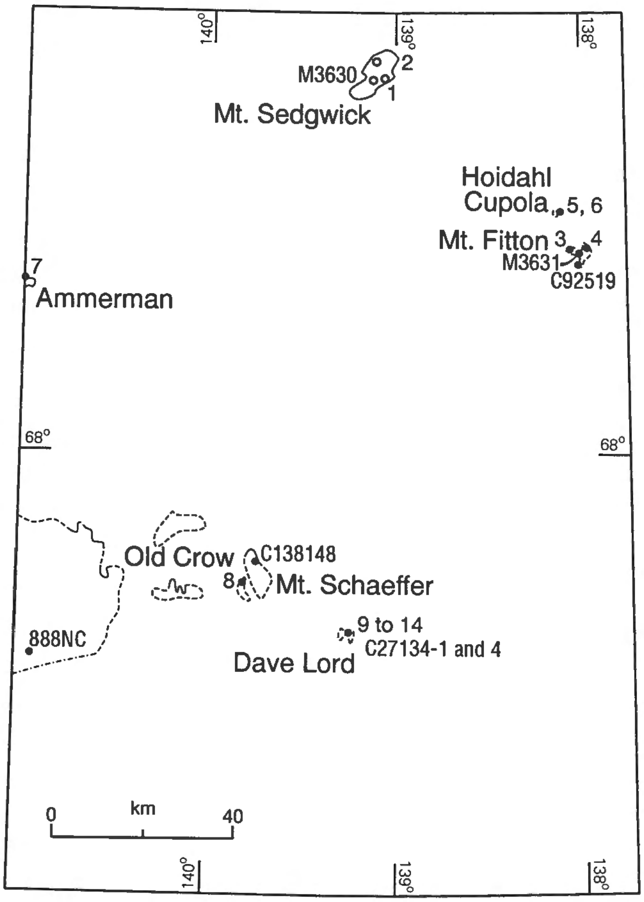

Figure 14.1. *Location of northern Yukon intrusive rock bodies and sampled localities. Numbers 1 to 14 refer to chemically analysed samples (see Table 14.1). Other localities are identified by Geological Survey of Canada (**C**) or University of Alberta (**M**) collection numbers.*

A Rb-Sr geochronologic study by K. Bell (unpub. rep., 1985) showed that many intrusions in the region have been subjected to post-emplacement alteration which has accelerated the present-day weathering processes. Alteration of the feldspars in many of the rocks rendered staining of the thin sections impractical, so modal analyses are based on visual estimates rather than point counting.

X-ray fluorescence spectroscopy (XRF) analyses for major and minor elements were carried out on 14 samples. Uranium was determined by delayed neutron counting, and thorium was determined by induced neutron activation analysis (INNA). Chemical and mineralogical data are presented in Table 14.1.

Petrography

A petrographic study of 21 thin sections from seven plutons indicated that six were in a restricted range of granite to granodiorite composition (Fig. 14.2). The Dave Lord pluton lies in the syenite–nepheline syenite field (Streckeisen, 1976). In the descriptions which follow, the sample numbers refer to Table 14.1 and Figure 14.1 and the corresponding field or catalogue numbers are given in brackets where appropriate.

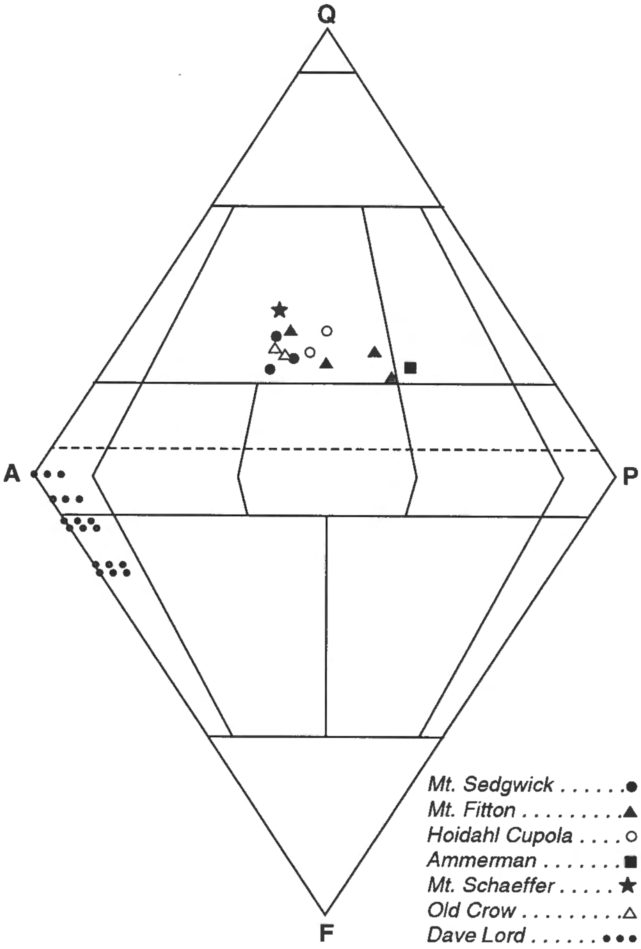

Figure 14.2. *Classification of samples based on estimated percentages of quartz (Q), alkali feldspar (A), plagioclase (P) and feldspathoid (F) minerals (Streckeisen, 1967). Six plutons cluster in the granite and granodiorite fields. The Dave Lord syenites have a single feldspar phase, with a ratio A:P probably greater than 9:1.*

Mount Sedgwick Pluton

Rock Type. Biotite hornblende granite.

Samples. 1 (525 NC), 2 (C92520), M3630.

Area. 65 km^2.

Petrography. The rock is a medium-light grey to greenish grey, medium to coarsely crystalline, locally porphyritic granite. Phenocrysts of perthitic orthoclase, up to 1 cm in length, poikilitically enclose plagioclase. Euhedral to subhedral plagioclase is strongly zoned, with composition ranging from An_{45} (core) to An_{25} (rim). The plagioclase is almost invariably altered to sericite and epidote while the orthoclase is relatively fresh. Biotite, the main mafic mineral, is strongly chloritized. Sample 1 contains hornblende with calcitic alteration. Magnetite, titanite and apatite, the accessory minerals, are not diagnostic since they are almost universal in rocks of this class.

Mount Fitton Pluton

Rock Type. Biotite hornblende granite.

Samples. 3 (M6045), 4 (M6049), C92519, M3631.

Area. 8 km^2.

Petrography. The samples range from light grey to medium grey with medium to coarse crystal size. Sample 3 is equigranular; the other samples are porphyritic, with subhedral phenocrysts of perthitic orthoclase ranging to 15 mm in length. The euhedral to subhedral plagioclase grains are commonly strongly zoned, showing andesine cores and oligoclase rims. These cores are commonly altered to white mica; the rims are less altered but are partly resorbed. The orthoclase shows a dusting of clay minerals and chlorite replaces most of the biotite. Hornblende remains relatively unaltered. Quartz shows moderate strain shadows but there is little other evidence of shearing. Allanite occurs as an accessory mineral in sample 4. Foliation is not evident in hand specimens; the rock is best described as massive.

Hoidahl Cupola

Rock Type. Biotite granite.

Samples. 5 (564NC 1A), 6 (564NC 1B).

Area. 1 km^2.

Petrography. The medium-light grey granite of Hoidahl differs from Mount Fitton mainly in texture. A finely crystalline matrix of quartz and orthoclase encloses phenocrysts of plagioclase, orthoclase, quartz and biotite. The euhedral, partly corroded, tabular plagioclase phenocrysts are zoned with complex twin laws, especially in the calcitic andesine cores. The rims are An_{20} oligoclase. Orthoclase phenocrysts poikilitically enclose plagioclase and numerous small books of biotite. Quartz aggregates up to 8 mm in length have outlines suggestive of quartz bipyramids. Quartz is also an important constituent of the fine grained matrix and is the filling for miarolitic cavities. Biotite occurs as euhedral to subhedral books, partly altered to chlorite.

The finely crystalline matrix (<0.25 mm) which constitutes about 50 per cent of the volume of sample 5 gives it the appearance of a hypabyssal porphyry. In the absense of field data, it is inferred to be a dyke rock. The matrix of sample 6, constituting approximately 25 per cent of the rock volume, is of the same fine crystal size. The texture indicates that this igneous body may be the upper tip of an epizonal pluton or a minor offshoot of the main Mount Fitton intrusive.

Ammerman

Rock Type. Hornblende biotite granodiorite.

Sample. 7 (C92516).

Area. 2 km^2.

Petrography. Megascopically, sample 7 from Ammerman resembles sample 3 from the western margin of Mount Fitton. The major difference appears to be in the degree of alteration. In sample 7, plagioclase composition is indeterminate and K-feldspar can be recognized only in rare patches within the sericitic alteration. The high K_2O content of the rock suggests hydrothermal alteration. Hornblende and biotite, present in approximately equal amounts, are partly altered to clinozoisite and chlorite.

The texture of sample 7 is hypidiomorphic-granular, with an average crystal size in the range 1 to 2 mm and with sparse phenocrysts of plagioclase up to 5 mm. Quartz occurs only as anhedral infillings between the feldspars. The geographic coordinates place this sample on the margin of the Ammerman pluton. Its texture is suggestive of a rapidly cooled magma.

Table 14.1

Major and trace element whole-rock analyses and modal mineralogy of selected samples of northern Yukon intrusive rocks. Modal compositions are estimated from single thin sections

Element	Mount Sedgwick		Mount Fitton		Hoidahl		Ammerman
	1	2	3	4	5	6	7
SiO_2	65.74	71.12	65.15	69.66	64.65	68.83	65.62
TiO_2	0.52	0.27	0.49	0.34	0.42	0.35	0.36
Al_2O_3	15.23	14.26	15.27	13.88	15.05	14.87	16.01
Fe_2O_3	4.64	2.19	5.28	3.75	5.73	3.96	3.41
MnO	0.06	0.04	0.07	0.05	0.11	0.05	0.06
MgO	1.85	0.62	2.61	1.20	2.42	1.29	0.93
CaO	3.45	2.26	2.92	2.82	3.42	2.33	2.26
Na_2O	3.16	3.20	2.18	3.13	2.78	2.82	2.51
K_2O	4.26	4.82	4.66	3.80	3.56	3.66	6.64
P_2O_5	0.25	0.10	0.14	0.22	0.12	0.15	0.12
LOI	1.49	1.09	1.57	0.69	2.36	1.29	1.69
Total	100.64	99.97	100.33	99.53	100.59	99.60	99.61
Nb	27	22	17	22	17	14	12
Zr	174	127	151	191	146	156	162
Y	20	15	23	20	18	21	20
Sr	670	403	319	398	309	293	201
Rb	223	205	208	197	166	150	306
Ba	854	1328	974	861	1014	1127	967
Ga	18	12	14	13	15	14	15
U	8.48	9.19	3.07	9.41	4.15	5.93	4.08
Th	37.0	30.0	16.0	45.0	14.0	15.0	25.0
Y + Nb	47	37	40	42	35	35	32
q	20	25	20	25	25	30	20
pg	25	30	45	40	30	35	45
k-fel	40	40	25	25	35	30	20
ne	—	—	—	—	—	—	—
bi	2	3	5	4	8	5	6
h	4	—	5	2	—	—	8
gt	—	—	—	—	—	—	—
fl	—	—	—	—	—	—	—
mag	<1	1	tr	<1	—	—	1
ti	<1	<1	tr	<1	—	—	<1
ru	tr	—	—	—	tr	—	—
ap	<1	tr	tr	tr	tr	tr	tr
zr	—	—	—	tr	tr	tr	—
alln	—	—	—	tr	—	—	—
mu	—	—	—	—	—	—	—
he	—	—	—	—	—	—	—
ch	6	1	x	<1	2	<1	x
ep	tr	—	x	—	—	x	x
sc	xx	—	xx	—	xx	xx	xx
ca	tr	—	—	—	x	—	—
pg(An)	46	35	48	40	47	48	nd

Table 14.1 (cont'd.)

Element	Old Crow	Dave Lord					
	8	9	10	11	12	13	14
SiO_2	74.87	55.35	57.44	59.82	62.79	52.26	54.16
TiO_2	0.12	0.23	0.14	0.35	0.14	0.30	0.16
Al_2O_3	13.03	22.34	23.64	20.38	18.01	20.95	21.64
Fe_2O_3	1.10	2.90	2.18	3.20	2.00	4.32	2.70
MnO	0.03	0.18	0.13	0.17	0.11	0.25	0.17
MgO	0.21	0.05	0.12	0.50	0.07	0.16	0.07
CaO	0.70	2.17	0.40	0.45	2.91	4.79	2.16
Na_2O	2.79	1.81	1.95	3.63	5.82	4.50	8.56
K_2O	5.69	11.25	11.77	9.93	7.74	8.01	8.58
P_2O_5	0.05	0.04	0.03	0.09	0.01	0.03	0.03
LOI	1.09	3.15	1.98	1.76	0.70	4.07	1.08
Total	99.68	99.47	99.79	100.26	100.29	99.64	99.31
Nb	31	536	470	164	228	531	287
Zr	63	756	341	354	965	1076	1123
Y	40	16	7	28	36	18	5
Sr	146	1115	1215	1830	647	2605	958
Rb	370	533	603	384	317	381	438
Ba	220	907	873	1828	857	741	531
Ga	23	26	28	17	31	27	33
U	9.9	93.9	83.7	7.37	22.7	96.2	41.3
Th	39	65.0	44.0	89.0	77.0	72.0	40.0
Y+Nb	71	552	447	192	264	549	292
q	30	—	—	—	—	—	—
pg	25	[	[	[	5	[	[
k-fel	40	[70	[75	[85	90	[90	[75
ne	—	20	20	10	?	5	10
bi	1	5	<1	<1	—	—	—
h	—	<1	—	—	—	1	3
gt	—	<1	2	3	2	3	—
fl	tr	2	1	<1	1	1	10
mag	tr	1	<1	<1	<1	<1	<1
ti	tr	tr	tr	<1	<1	tr	1
ru	—	—	—	—	—	—	—
ap	tr	tr	tr	tr	tr	<1	<1
zr	tr	tr	—	tr	tr	tr	tr
alln	tr	tr	—	—	—	—	—
mu	tr	—	—	<1	—	—	—
he	—	—	<1	x	x	—	—
ch	3	—	—	x	—	—	<1
ep	tr	—	x	—	—	—	—
sc	x	xx	xx	xx	xx	x	—
ca	tr	x	—	—	—	—	—
pg(An)	32	nd	nd	nd	10	nd	10

Major elements are measured in wt.%, minor elements in ppm. Mineral composition is an estimated modal. Trace (tr); disseminated alteration (x); abundant alteration products (xx); not determined (nd); perthitic orthoclase ([).

Old Crow

Rock Type. Biotite granite.

Samples. 8 (M3632), 888 NC.

Area. 1700 km^2.

Petrography. The coarsely crystalline, leucocratic granite consists mainly of perthitic orthoclase, up to 10 mm in length, poikilitically enclosing resorbed, saussuritized oligoclase. Where the altered plagioclase is not completely enclosed in orthoclase, it is commonly rimmed by fresh albite. In some oligoclase cores there are small euhedral muscovite books, apparently derived by recrystallization from the finer crystalline mat of alteration products. Muscovite also forms parallel overgrowths on some chlorite flakes which are pseudomorphs of biotite. The fresh albite and muscovite suggest that the rock may have been subject to low-grade regional metamorphism after crystallization. There is little evidence of deformation in the quartz; it occurs as large aggregates with moderate strain shadows.

Biotite is almost completely altered to chlorite. Traces of fluorite occur with the muscovite and along biotite cleavages. A trace of allanite is the only diagnostic accessory mineral.

Mount Schaeffer

Rock Type. Biotite tourmaline granite.

Sample. C138148

Area. 60 km^2.

Petrology. This medium-light grey, medium crystalline granite contains accessory tourmaline and traces of fluorite. Perthitic orthoclase and zoned euhedral to partly resorbed oligoclase tablets are enclosed in a mosaic of dark grey quartz. The biotite is largely altered to chlorite and the calcic cores ($\approx An_{30}$) of the plagioclase are saussuritized. Tourmaline, muscovite and fluorite are late accessory minerals.

Dave Lord

Rock Type. Nepheline syenite to syenite.

Samples. C27134 (998NC-1 to 5), HED 1 to 3.

Area. 6 km^2.

Petrography. Although this small pluton shows considerable range in mafic mineral content, all samples examined can be classed as leucocratic syenite to hornblende nepheline syenite. The fabric varies from medium crystalline equigranular to porphyritic to trachytic. In most thin sections only one feldspar phase, highly perthitic orthoclase with chessboard twinning of the exsolved albite, can be recognized. When present, nepheline is almost completely replaced by sericite. None of the thin sections contain quartz. The varietal minerals are melanite, biotite, hornblende and fluorite, each less than 5 per cent. The accessory minerals are magnetite, titanite, apatite, allanite and zircon. The late infilling of miarolitic cavities by fluorite suggests epizonal emplacement of the pluton.

GEOCHEMISTRY

Major element compositons (Table 14.1) effectively divide the samples into two groups: the Dave Lord pluton, and all other intrusives. The syenitic nature of Dave Lord pluton is evident in the SiO_2, Al_2O_3 and K_2O contents. CIPW norms show the Dave Lord samples to be nepheline normative; samples from other intrusions are quartz normative.

Trace element discrimination diagrams have been widely used to divide igneous rocks into groups with different magmatic histories. Pearce et al. (1984) suggest a number of trace element ratios which can be applied to the tectonic discrimination of granitoid rocks. The northern Yukon analyses are plotted on two discrimination diagrams: Nb vs. Y (Fig. 14.3), and Rb vs. Y+Nb (Fig. 14.4).

Analyses of samples of all but the Dave Lord pluton form a tight cluster on both diagrams. On Figure 14.3, the cluster lies in the volcanic arc granite (VAG)/syn-collision granite (syn-COLG) field, well removed from the ocean-ridge granites (ORG) but proximal to the within-plate granites (WPG). On Figure 14.4, the cluster lies on the VAG/syn-COLG boundary. The wedge-shaped area at the upper right of VAG on Figure 14.4 was shown by Pearce et al. (1984, fig. 6) to be the field of post-collision granites, which they were unable to define rigorously. The examples given by Pearce et al. (op. cit.) are from the Hercynian and Alpine orogenic belts. In the Caledonian belt of Great Britain, the "Late Granites", which Read (1957) described as arriving in the epizone "almost dead", may be the classic examples of post-collision granites.

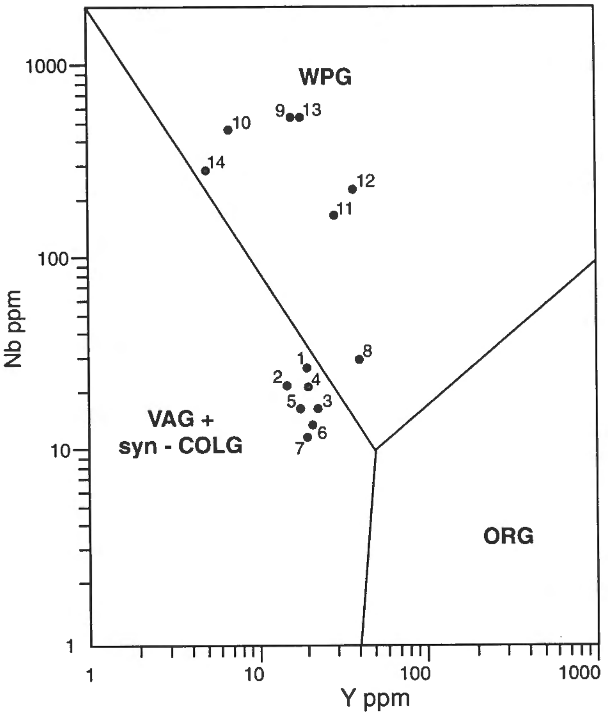

Figure 14.3. *Plot of Nb vs. Y, trace element discrimination diagram (Pearce et al., 1984). Numbers 1 to 14 refer to chemically analysed samples (see Table 14.1). Empirical divisions of intrusions between tectonic settings: within plate granites (WPG); volcanic arc granites (VAG); syn-collision granites (syn-COLG); ocean ridge granites (ORG).*

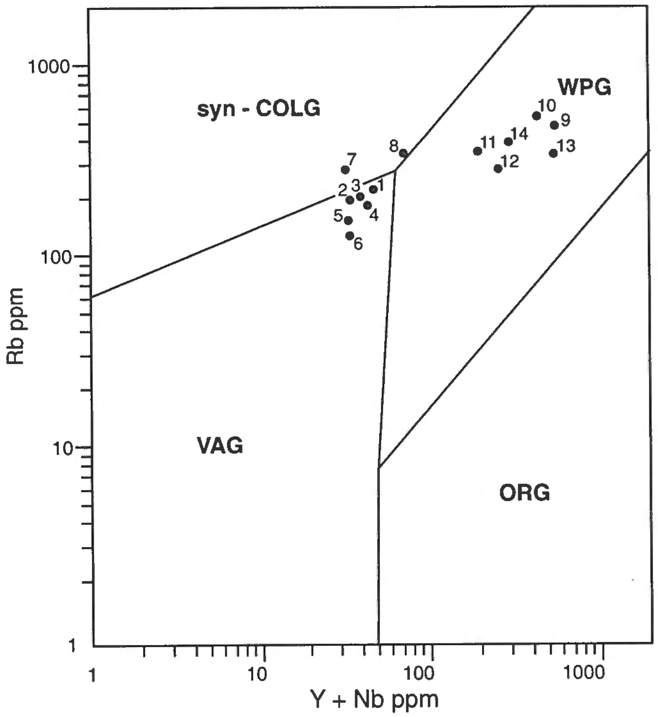

Figure 14.4. *Plot of Rb vs. Nb + Y, discrimination diagram. See Figure 14.3 for designation of the fields.*

The trace element composition of the post-collision granites requires a mixture of mantle- and crust-derived magmas. Samples 1 to 8 on Figure 14.4 seem to fit this category. The undeformed nature of the rocks support this assignment.

Six analyses of the Dave Lord pluton form clusters in the WPG field, clearly distinct from samples 1 to 8 on both Figures 14.3 and 14.4. The low SiO_2 and high K_2O of the Dave Lord pluton is strongly suggestive of differentiation from a potassic alkali basalt source at depth. The elevated Rb, Zr, U and Th contents are also indicative of such an origin (Burwash and Cavell, 1978). The most likely tectonic setting is a post-orogenic extensional regime within the North American Plate.

Geochronology

Reconnaissance K-Ar dating of the northern Yukon granites by Baadsgaard et al. (1961) gave a mid-Paleozoic age of 353 Ma for the Mount Fitton pluton. Subsequent work by Wanless et al. (1965), Wanless et al. (1974) and K. Bell (unpub. rep., 1985) and Mortensen and Bell (1991) have contributed the limited data given in Table 14.2.

The majority of accepted dates fall in the time interval 340 to 370 Ma. In commenting on the Rb-Sr whole rock errorchrons, K. Bell (unpub. rep., 1985) suggested that the alteration of the primary minerals in many rock samples suggests a complex geological history. A number of isotopic ages in the range 95 to 300 Ma are not included in Table 14.2. These may represent the overprinting of the Paleozoic magmatic record by a series of Mesozoic thermal events related to Cordilleran tectonics.

Construction of a detailed chronology of events for the interval 340 to 370 Ma is not warranted by the available data. Two isotopic decay schemes, a variety of dated materials, three independent laboratories and technological changes over 25 years limit the value of close comparisons of the results. In spite of these limitations, it seems reasonable to assume that this series of plutons was emplaced in late Devonian to early Mississippian time.

Summary and conclusions

The intrusive rocks of northern Yukon appear to represent two distinctly different petrogenetic suites. With the exception of the Dave Lord, a granite-granodiorite association is typical of all the plutons. The quartz-alkali feldspar-plagioclase ratios (Fig. 14.2) and low colour indices (Table 14.1) of these rocks indicate that they may be magmas generated at the minimum melting point from a sedimentary wedge or from older crystalline basement. The Sr^{87}/Sr^{86} initial ratios for the Mount Sedgwick and Old Crow batholiths imply generation from recycled sial. The strongly zoned and partly resorbed plagioclase phenocrysts are consistent with early crystallization at depth, followed by movement into the epizone. The time of emplacement, as deduced from trace element discrimination diagrams (Figs. 14.3, 14.4), is post-collision. The lack of significant deformation visible in thin section suggests a late orogenic time frame.

The Dave Lord pluton belongs to a tectonic setting clearly indicated to be within the continental plate. The nepheline-normative rocks, which consist largely of orthoclase perthite, crystallized from a strongly undersaturated, highly potassic magma. Such magma is normally generated within the mantle and emplaced into a rigid plate during crustal extension. The Sr^{87}/Sr^{86} initial ratio of the Dave Lord pluton shows a mantle signature (K. Bell, unpub. rep., 1985).

Geochronologic data are not precise enough to allow us to establish the relative ages of the various plutons. If all of the intrusions are judged to be coeval, then their different tectonic environments must have been juxtaposed after intrusion. The major northeast trending fault which separates the Dave Lord intrusion from the Old Crow and Mount Schaeffer plutons may mark the boundary between tectonic domains.

An alternative explanation is a 60 to 80 million year cycle of deformation and intrusion including synkinematic to late kinematic collisional granites and an episode of post kinematic extensional syenite intrusion. This theory accommodates the spread of isotopic age determinations: these vary from a K-Ar date of 431 ± 13 Ma for hornblende from the Romanzof granite pluton found in the Brooks Range of Alaska (Reiser, 1970) to 352 ± 5 Ma for the Rb-Sr isochron (K. Bell, unpub. rep., 1985) of the Dave Lord mantle-derived syenite. Although an analogy for this interpretation is Cretaceous compression followed by

Table 14.2
Age determinations for northern Yukon intrusions
(Recalculated using currently accepted decay constants from Steiger and Jager, 1977)

Plutons/Sample	Method	Material	Result (Ma)	Reference/Comments
Mount Sedgwick				
GSC 63-16	K-Ar	Hbl	361	Wanless et al. (1965)
GSC 73-57	K-Ar	Hbl	348	Wanless et al. (1974)
GSC 73-58	K-Ar	Hbl	320	Wanless et al. (1974)
SE 100-106	Rb-Sr	WR	249 ± 31	K. Bell (unpub. rep., 1985), Errorchron I.R. 0.7121 ± 0.0004
Loc. A	U-Pb	Zr and Ti	370 ± 1	Mortensen and Bell (1991)
Mount Fitton				
AK 51	K-Ar	Biot.	363	Baadsgaard et al. (1961)
GSC 63-15	K-Ar	Biot.	376	Wanless et al. (1965)
Old Crow				
GSC 63-14	K-Ar	Biot.	269	Wanless et al. (1965)
OCB 102-112	Rb-Sr	WR	365 ± 8	K. Bell (unpub. rep., 1985), Errorchron I.R. 0.7275 ± 0.0005
Dave Lord				
DL 100-108	Rb-Sr	WR	352 ± 5	K. Bell (unpub. rep., 1985), Isochron I.R. 0.7026 ± 0.0001

Tertiary extension in the southern part of the Canadian Cordillera, more detailed petrologic, structural and geochronological data are required to substantiate theories pertaining to the true nature of the igneous history of northern Yukon.

Acknowledgments

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Light-weathering 370 MA biotite hornblende granite of the Mount Fitton pluton on the east flank of Barn Mountains. The granite is hosted in the lower Paleozoic Road River Formation and is in fault contact with Lower Cretaceous clastics of the twin peaks. View is to the northwest. GSC photo 1860-40.

CHAPTER 15

MINERAL AND HYDROCARBON POTENTIAL

D.K. Norris and O.L. Hughes*

Norris, D.K. and Hughes, O.L., 1996. Mineral and hydrocarbon potential. In The Geology, Mineral and Hydrocarbon Potential of Northern Yukon Territory and Northwestern District of Mackenzie. Geological Survey of Canada, Bulletin 422, p. 369–394.

Abstract

A wide variety of nonrenewable commodities of economic interest to mining and oil companies occurs in northern Yukon Territory and western District of Mackenzie. They range from coal, iron, uranium, lead and zinc in the mountainous southern part of the area, to oil and gas in the Eagle Plain, placer gold in the Yukon Coastal Lowland, construction materials in the Northern Interior Platform, and oil and gas in the Mackenzie Delta and the continental shelf of southern Beaufort Sea. Of singular importance are the enormous tonnages of phosphatic iron in the northwestern Mackenzie Mountains, the very large tonnages of subbituminous to high volatile bituminous coal nearby in the Bonnet Plume Basin, and the numerous discoveries of oil and gas on the continental shelf. Although the resource potential of many of these commodities is reasonably well known, only the construction materials have been exploited commercially. The region remains a storehouse of economic minerals and hydrocarbons for Canada's future.

Résumé

Le nord du Yukon et l'ouest du district de Mackenzie recèlent une vaste gamme de substances utiles non renouvelables offrant un intérêt économique pour les sociétés minières et pétrolières. Ces substances varient de charbon, fer, uranium, plomb et zinc dans la partie méridionale montagneuse de la région, à du pétrole et gaz dans la plaine Eagle, à de l'or alluvionnaire dans les basses terres côtières du Yukon, à des matériaux de construction dans le nord de la Plate-forme de l'Intérieur et au pétrole et au gaz dans le delta du Mackenzie et la plate-forme continentale du sud de la mer de Beaufort. Il faut noter l'importance particulière des vastes réserves de fer phosphatique dans le nord-ouest des monts Mackenzie, les très grandes quantités de charbon subbitumineux à bitumineux très volatil dans le bassin voisin de Bonnet Plume et les nombreuses découvertes de pétrole et de gaz dans la plate-forme continentale. Même si le potentiel d'un grand nombre de ces substances est raisonnablement bien connu, seul les matériaux de construction ont été exploités commercialement. Cette région demeure un entrepôt de minéraux et d'hydrocarbures pour l'avenir économique du Canada.

INTRODUCTION

The project area embraces a wide variety of nonrenewable commodities of economic interest to mining and oil companies. They range from occurrences of oxides of uranium and sulphides of lead and zinc in the southern part of the area, to oil and gas beneath the continental shelf of southern Beaufort Sea. The various commodities are located on Figures 15.1 and 15.2. They are listed in Table 15.1 and their distribution, according to tectonic element, is presented in Table 15.2.

The first reported occurrences of these commodities were, as might be expected, along the major transportation routes of the fur traders, including navigable streams and the coastline of the Beaufort Sea. However, with the advent of the airplane, first the fixed-wing and later the helicopter, inaccessibility of

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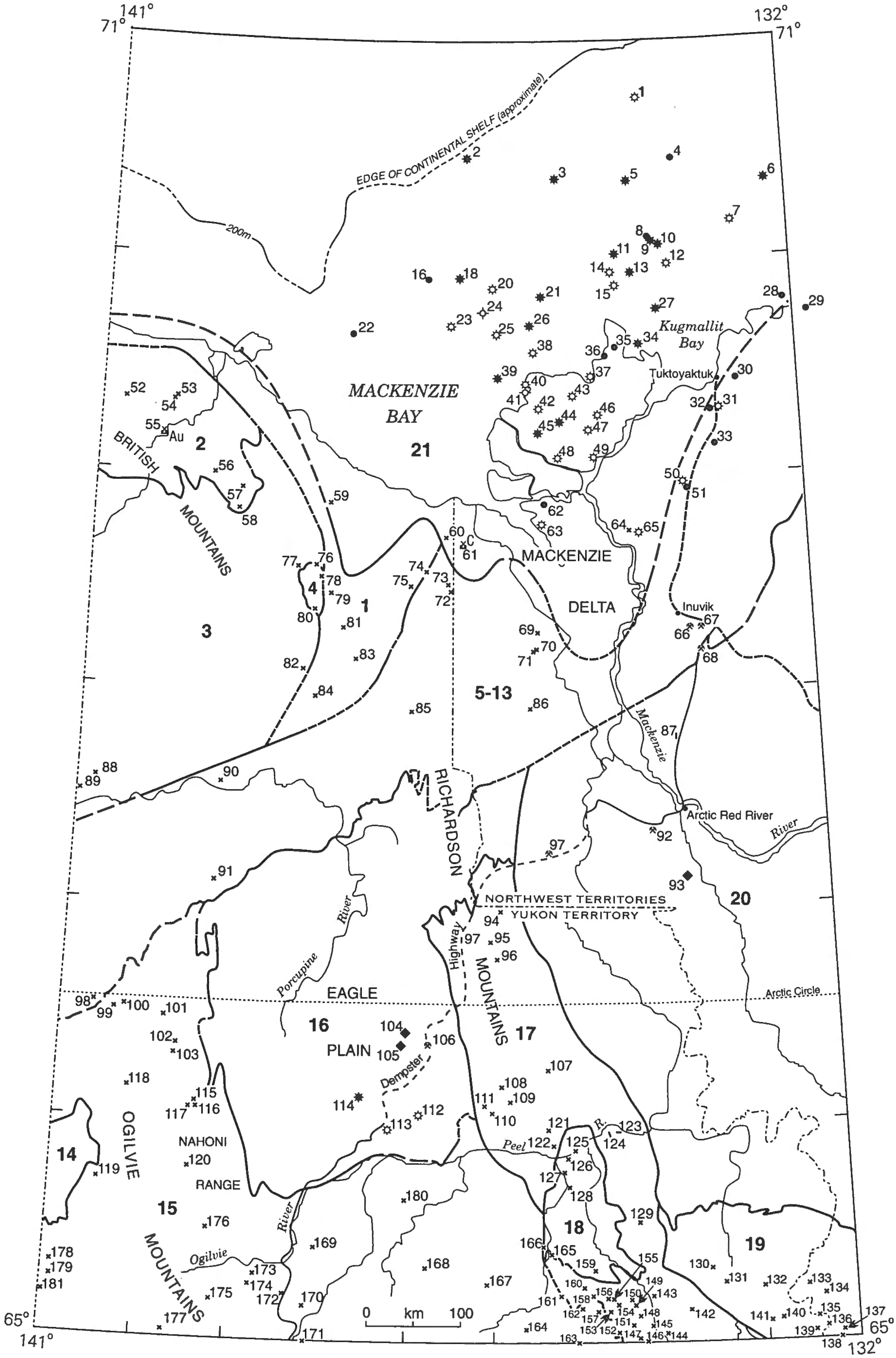
*Deceased 1992


141°
71°
132°
71°
65°
141°
65°
132°
EDGE OF CONTINENTAL SHELF (approximate)
200m
MACKENZIE BAY
21
Kugmallit Bay
Tuktoyaktuk
BRITISH MOUNTAINS
Au
2
3
4
1
C
MACKENZIE DELTA
5-13
Inuvik
Mackenzie
Arctic Red River
River
RICHARDSON MOUNTAINS
NORTHWEST TERRITORIES
YUKON TERRITORY
Highway
Dempster
20
Porcupine River
EAGLE PLAIN
16
17
Arctic Circle
OGILVIE MOUNTAINS
NAHONI RANGE
14
15
Peel R.
18
19
Ogilvie River
0 km 100

Mineral occurrence	×
Quarry (gravel, limestone,dolomite, sandstone)	⚒
Mine, abandoned (gold, coal)	⛏
Seep (gas, oil)	◆
Intrusion (bitumen)	/
Well (oil, gas, oil and gas, dry and abandoned)	● ☼ ✸ ⌖
Locality number (Tables 15.1 and 15.3)	52

Figure 15.1. *Geographic location and tectonic setting of known mineral and significant hydrocarbon occurrences. Tectonic elements are by number: 1, Rapid Depression; 2, Romanzof Uplift; 3, Old Crow–Babbage Depression; 4, Barn Uplift; 5–13, Aklavik Arch Complex; 14, Kandik Basin; 15, Taiga–Nahoni Foldbelt; 16, Eagle Foldbelt; 17, Richardson Anticlinorium; 18, Bonnet Plume Basin; 19, Mackenzie Foldbelt; 20, Northern Interior Platform; 21, Beaufort–Mackenzie Basin.*

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the interstream areas became a thing of the past. This remote region of northwestern Canada was open to exploration. On the mainland, the systematic coverage of the ground with air photographs, during and following World War II, led to the production of accurate topographic maps, the study and delineation of areas of potential mineralization and hydrocarbon traps, and ultimately the designation of routes of access to these areas. In turn, the region was subject to systematic, air-supported mapping and assessment with ground control. It began in 1953 with the investigation of the hydrocarbon potential of the Eagle Foldbelt by Peel Plateau Exploration Ltd. This investigation led directly to the discovery of gas and oil in Western Minerals Chance No. 1 well on the Chance Anticline in 1959.

In the Mackenzie Delta and offshore, regional airborne magnetic and gravity surveys, and shipborne seismic surveys have led to the location and identification of scores of structural culminations with potential for trapping hydrocarbons. Moreover, ice-reinforced ships, artificial islands, caisson-retained islands, ice-resistant drilling platforms and spray-ice islands have enabled the drilling of many of these traps. The system chosen has been dictated largely by water depth. Discoveries range geographically from the outer edge of the continental shelf (Nektoralik K-59) to the shallow waters of Mackenzie Bay (Adgo F-28) (Fig. 15.1).

Two hundred and forty-six wells have been drilled in the Beaufort Sea–Mackenzie Delta region (G.R. Campbell, pers. comm., 1991). Of these, 182 were exploratory wells and 64 were delineation wells. Thirty-one were drilled from artificial islands, 42 from drill ships or floating platforms, and 18 from caissons footed on subsea berms. Onshore, insulated pads specially designed to minimize melting of the permafrost were used. More than 50 significant hydrocarbon accumulations have been discovered (Table 15.3). Exploitation of these resources awaits the construction of suitable all-season means of transport, principally to North American markets. The Mackenzie Valley pipeline for gas and later for oil is the current favourite route for delivery.

METALLIC MINERALS AND GYPSUM

Ninety-one occurrences of metallic minerals and gypsum reported from the project area are shown on Figure 15.1. In Table 15.1 they are grouped according to the National Topographic System along with their tectonic setting and development status. It is immediately apparent from both Tables 15.1 and 15.2 that they are confined largely to structurally positive elements—Mackenzie Foldbelt, Richardson Anticlinorium, Taiga-Nahoni Foldbelt and Romanzof Uplift—and that in most instances, insufficient data are available for the calculation of ore reserves. They are hosted, with few exceptions, within Middle Devonian and older formations (see 1:250 000 scale geological maps and reports referred to in Table 15.1).

There are a number of references that treat these occurrences comprehensively, not only for the project area but also for all of Yukon Territory and adjacent District of Mackenzie. These include Energy, Mines and Resources Canada (EMR) (1980a, 1980b, 1981), Findlay et al. (1986), Sinclair et al. (unpub. rep., 1981), and the Department of Indian Affairs and Northern Development (DIAND) (1993). The results of regional stream-silt geochemical surveys over the northern part of the project area have been reported by Goodfellow (1979). Those occurrences considered to be economically significant are included in this chapter, supplemented by others that have not been reported to date.

Mackenzie Foldbelt

Iron, barium, zinc, lead and gypsum mineralization is reported from the northwestern Mackenzie Foldbelt within the project area. By far the most significant is the bedded, phosphatic iron formation in the Hadrynian Rapitan Formation at the headwaters of Snake River (Crest Explorations Ltd., unpub. rep., 1963; 106 F1/1, 106 F1/2 and 106 F2/3 on Table 15.1). It is a persistent horizon up to 120 m thick, composed of red chert interlayered with blue specular hematite,

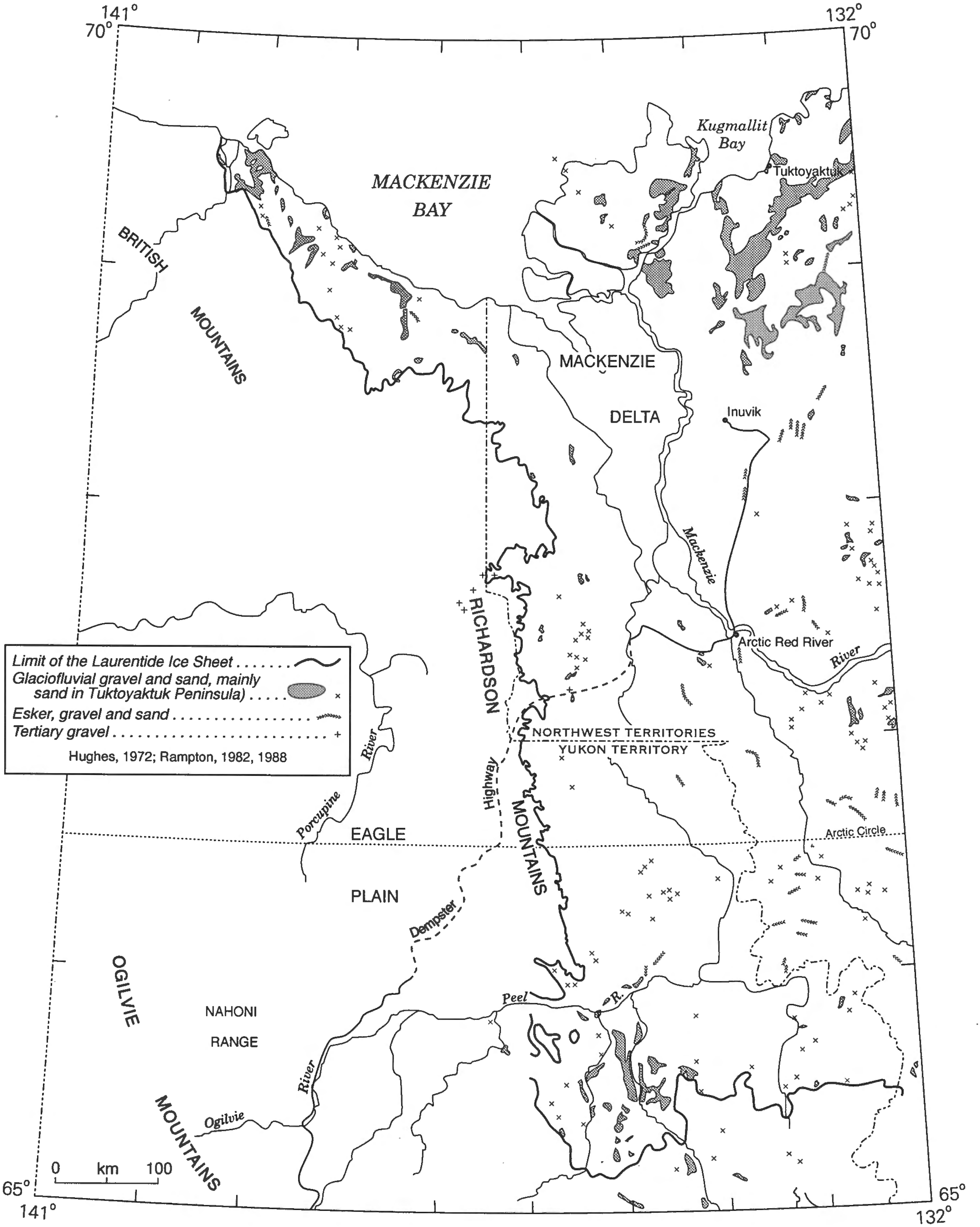

Figure 15.2. *Areal distribution of Tertiary and Laurentide construction materials in eastern Yukon Territory and western District of Mackenzie.*

occurring in the lower part of the glacial-marine Rapitan Formation. Preliminary, unconfirmed reports (e.g., Canada Month, 1962) suggested reserves in the order of 100 billion tonnes. A more recent conservative estimate (Sinclair et al., unpub. rep., 1981) is that there are more than 18 billion tonnes of iron resources in the Snake River area.

Second in importance is the occurrence of bedded gypsum in the upper part of the Helikian Little Dal Formation (106 F5/1) in the Snake River area northwest of the iron formation. A seam of the mineral outcrops widely, and pinches and swells from a few metres to an estimated 100 m. It is speculated that the gypsum intrusions in the northern Richardson Anticlinorium (106 L13/1) and on the north flank of the Aklavik Arch Complex (107 B4/1 and 107 B5/1) arise from this stratigraphic level. Should this be the case, the gypsum seam(s) would appear to be very widespread along this portion of the eastern flank of the Cordillera.

Of tertiary importance is the occurrence of barite as veins near the contact between the Cambro-Ordovician Franklin Mountain Formation and the overlying Road River Formation (106 F1/3), and carbonate-hosted zinc and lead in the Franklin Mountain Formation (106 F1/4) in the extreme southeast corner of the project area. The potential for additional zinc-lead deposits of this type is rated as very high (Sinclair et al., unpub. rep., 1981) because such mineralization may occur at several horizons in the Proterozoic–lower Paleozoic section.

Richardson Anticlinorium

The most significant mineralization within the anticlinorium occurs in association with diatreme breccias observed to cut the mid-Proterozoic Fairchild Lake and Quartet groups in northern Wernecke Mountains at the headwaters of Bonnet Plume River (106 E1/1, 106 E1/2, etc.), and at the headwaters of Caribou River (106 L3/1). Locally, both breccia and host rocks are feldspathised and barite, iron, copper, cobalt and uranium minerals, individually or collectively, may be present (Archer et al., 1977).

Of secondary importance are the zinc-lead mineralization on the west flank of the anticlinorium (116 I1/1, 116 I1/2, etc.), the zinc mineralization axially on the anticlinorium a few kilometres north of Peel River (106 E14/3 and 106 E14/4), and the gypsum intrusion along a strand of Richardson Fault Array (106 L13/1) close to the northern limit of the anticlinorium.

Taiga–Nahoni Foldbelt

The carbonate rocks comprising the Middle Devonian and older Paleozoic formations of the Taiga and Nahoni ranges are the principal hosts for a scattered array of occurrences of lead, zinc, copper, silver and barium mineralization. Among these, the most promising occurrence is 116 K9/2 ("Rusty Springs"; Rio Alto Exploration Ltd., 1976) in northern Nahoni Range. There, the Lower and Middle Devonian Ogilvie Formation appears to host copper, zinc and silver minerals. Little is known of the companion copper, lead and zinc occurrences at 116 J5/1 and 116 J5/2, except that they are hosted stratigraphically lower in the undifferentiated Middle Devonian and older carbonate bank ("ЄDb") beneath the Ogilvie.

Minor occurrences of lead and zinc mineralization are also known in lower Paleozoic carbonate rocks of the Taiga Ranges. In the upper Wind River area opposite Royal Mountain (106 E2/1 and 106 E3/1), sphalerite and galena are reported from the Lower Cambrian (Dawson, 1975). In the Hart River area they are known in the Road River Formation (116 H10/1) and at the top of "ЄDb" (116 H7/1). Along upper Ogilvie River they occur within "ЄDb" (116 G3/1), and in western Ogilvie Mountains in the Cambro-Ordovician Jones Ridge limestone (116 F2/1 etc.).

Massive oolitic magnetite occurs in the lower part of the Jurassic and Lower Cretaceous Kingak Formation on the east flank of Porcupine Anticline of northern Ogilvie Mountains (116 K9/1; Norris, 1976, p. 461). Its appearance as a layer-parallel horizon suggests that the lower part of the Kingak is prospective for iron elsewhere. Hematitic iron, moreover, has been reported from the upper, Hadrynian part of the Tindir Group along the Alaska border (Cairnes, 1914, p. 53). It would appear to be coeval with the hematite iron formation mentioned above (106 F1/1 etc.) in northwestern Mackenzie Mountains.

Barite in veins and pods is hosted in "ЄDb" at the headwaters of Ogilvie River (116 G1/3 etc.) close to Dempster Highway. Additional minor mineral occurrences include those of copper, lead and zinc, reported from the Permian Tahkandit Formation exposed in the core of Mink Anticline (116 K1/1) at the headwaters of Fishing Branch River (EMR, 1980a); and vivianite-rich ironstone nodules in the Middle and Upper Triassic Shublik Formation (116 G4/1) at the headwaters of Ogilvie River.

Table 15.1

Commodity occurrences grouped by NTS area, with tectonic setting, status and key reference

NTS area/ Commodity no.	Tectonic element	Commodity	Status*	Reference	Locality no.
Metallic Minerals and Gypsum					
106 E1/1	Richardson Anticlinorium	Cu	7	Norris, 1982a	145
106 E1/2	Richardson Anticlinorium	U	7	DIAND, 1993	147
106 E1/3	Richardson Anticlinorium	U	7	DIAND, 1993	144
106 E1/4	Richardson Anticlinorium	U	7	DIAND, 1993	148
106 E1/5	Richardson Anticlinorium	U	7	DIAND, 1993	150
106 E1/6	Richardson Anticlinorium	U	7	DIAND, 1993	149
106 E1/7	Richardson Anticlinorium	Zn, Pb	7	DIAND, 1993	143
106 E1/8	Richardson Anticlinorium	Cu	7	DIAND, 1993	151
106 E1/9	Richardson Anticlinorium	U, Cu	7	DIAND, 1993	146
106 E2/1	Taiga–Nahoni Foldbelt	Zn, Pb	7	Dawson, 1975	157
106 E2/3	Richardson Anticlinorium	Cu, U	7	DIAND, 1993	152
106 E2/4	Richardson Anticlinorium	Cu	7	DIAND, 1993	154
106 E2/5	Richardson Anticlinorium	Zn	7	DIAND, 1993	155
106 E2/6	Richardson Anticlinorium	U	7	DIAND, 1993	156
106 E2/7	Richardson Anticlinorium	U	7	DIAND, 1993	153
106 E3/1	Taiga–Nahoni Foldbelt	Pb, Zn	7	Dawson, 1975	162
106 E3/2	Taiga–Nahoni Foldbelt	Pb, Zn	7	DIAND, 1993	163
106 E4/1	Taiga–Nahoni Foldbelt	Pb, Zn	7	DIAND, 1993	164
106 E9/1	Richardson Anticlinorium	Zn, Pb	7	DIAND, 1993	129
106 E14/3	Richardson Anticlinorium	Pb, Zn	7	DIAND, 1993	121
106 E14/4	Richardson Anticlinorium	Zn	7	DIAND, 1993	122
106 F1/1	Mackenzie Foldbelt	Fe	2	Crest Explorations Ltd., unpub. rep., 1963	133
106 F1/2	Mackenzie Foldbelt	Fe	2	Crest Explorations Ltd., unpub. rep., 1963	134
106 F1/3	Mackenzie Foldbelt	Ba	7	Norris, 1982b	136
106 F1/4	Mackenzie Foldbelt	Zn, Pb	7	Dawson, 1975	137
106 F1/5	Mackenzie Foldbelt	Zn	7	DIAND, 1993	138
106 F1/6	Mackenzie Foldbelt	Zn	7	DIAND, 1993	139
106 F1/7	Mackenzie Foldbelt	Zn	7	DIAND, 1993	135
106 F2/1	Mackenzie Foldbelt	Zn	7	DIAND, 1993	141
106 F2/2	Mackenzie Foldbelt	Zn	7	DIAND, 1993	140
106 F2/3	Mackenzie Foldbelt	Fe	7	DIAND, 1993	132
106 F4/1	Richardson Anticlinorium	Zn	7	DIAND, 1993	142
106 F5/1	Mackenzie Foldbelt	gp	7	Norris, 1982b	130
106 F5/2	Mackenzie Foldbelt	Zn	7	DIAND, 1993	131
106 L3/1	Richardson Anticlinorium	Fe, U, Cu	7	EMR, 1980a	107
106 L4/1	Richardson Anticlinorium	Pb, Zn	7	DIAND, 1993	108
106 L4/2	Richardson Anticlinorium	Pb, Zn	7	DIAND, 1993	109
106 L13/1	Richardson Anticlinorium	gp	7	Norris, 1981a	94
106 L13/2	Richardson Anticlinorium	Pb, Zn	7	DIAND, 1993	96
106 M13/1	Aklavik Arch Complex	Cu	7	EMR, 1980a	86
107 B4/1	Aklavik Arch Complex	gp	7	Norris, 1981b	71
107 B5/1	Aklavik Arch Complex	gp	7	Norris, 1981b	69
116 F2/1	Taiga–Nahoni Foldbelt	Zn, Pb	7	Norris, 1982c	179
116 F2/2	Taiga–Nahoni Foldbelt	Zn	7	DIAND, 1993	181
116 F7/1	Taiga–Nahoni Foldbelt	Zn, Pb, U	7	DIAND, 1993	178
116 G1/1	Taiga–Nahoni Foldbelt	Cu, Co	7	DIAND, 1993	171
116 G1/2	Taiga–Nahoni Foldbelt	Ba	7	DIAND, 1993	170
116 G1/3	Taiga–Nahoni Foldbelt	Ba	7	DIAND, 1993	172
116 G3/1	Taiga–Nahoni Foldbelt	Pb, Zn, Ag	7	Norris, 1982c	175
116 G4/1	Taiga–Nahoni Foldbelt	P	7	Norris, 1982c	177
116 G7/1	Taiga–Nahoni Foldbelt	Pb, Zn	7	DIAND, 1993	173
116 G7/2	Taiga–Nahoni Foldbelt	Ba, Pb	7	DIAND, 1993	174
116 G8/1	Taiga–Nahoni Foldbelt	Ba	7	DIAND, 1993	169
116 G11/1	Taiga–Nahoni Foldbelt	Pb	7	DIAND, 1993	176
116 G14/1	Taiga–Nahoni Foldbelt	Pb	7	DIAND, 1993	120
116 H7/1	Taiga–Nahoni Foldbelt	Pb, Zn, Cu	7	EMR, 1980a	168
116 H8/1	Taiga–Nahoni Foldbelt	Ba	7	DIAND, 1993	167
116 H10/1	Taiga–Nahoni Foldbelt	Pb, Zn	7	Norris, 1982d	180
116 I1/1	Richardson Anticlinorium	Zn, Pb	7	Norris, 1981c	111
116 I1/2	Richardson Anticlinorium	Zn, Pb	7	Norris, 1981c	110
116 I16/1	Richardson Anticlinorium	Zn	7	DIAND, 1993	95
116 J3/1	Taiga–Nahoni Foldbelt	Pb, Zn	7	DIAND, 1993	117
116 J3/2	Taiga–Nahoni Foldbelt	Pb, Zn	7	DIAND, 1993	116
116 J3/3	Taiga–Nahoni Foldbelt	Pb, Zn	7	DIAND, 1993	115
116 J5/1	Taiga–Nahoni Foldbelt	Pb, Zn	7	EMR, 1980a	102
116 J5/2	Taiga–Nahoni Foldbelt	Pb, Zn	7	EMR, 1980a	103
116 J5/3	Taiga–Nahoni Foldbelt	Pb, Zn	7	DIAND, 1993	101
116 K1/1	Taiga–Nahoni Foldbelt	Cu, Zn	7	DIAND, 1993	118
116 K9/1	Taiga–Nahoni Foldbelt	Fe	7	Norris, 1976	100
116 K9/2	Taiga–Nahoni Foldbelt	Ag, Zn, Cu	7	Rio Alto, 1976	99
116 K10/1	Aklavik Arch Complex	Fe, Zn	7	Norris, 1979	98
116 N10/1	Old Crow–Babbage Depression	W	7	EMR, 1980a	88
116 N10/2	Old Crow–Babbage Depression	Pb, Zn	7	DIAND, 1993	89

Table 15.1 (cont'd.)

NTS area/ Commodity no.	Tectonic element	Commodity	Status*	Reference	Locality no.
116 03/1	Aklavik Arch Complex	Zn	7	DIAND, 1993	91
116 O11/1	Aklavik Arch Complex	F, U	7	DIAND, 1993	90
116 O16/1	Rapid Depression	Sr, P, U, Cu	7	EMR, 1980a	84
117 A2/1	Rapid Depression	U	7	EMR, 1980a	83
117 A6/1	Barn Uplift	U	7	DIAND, 1993	80
117 A7/1	Rapid Depression	U, Mo, W	7	EMR, 1980a	79
117 A8/1	Rapid Depression	Fe, P	7	Norris, 1981d	75
117 A8/2	Aklavik Arch Complex	Fe, P	7	Norris, 1981d	72
117 A8/3	Aklavik Arch Complex	Fe, P	7	DIAND, 1993	73
117 A9/1	Rapid Depression	Fe, P	7	Sturman and Mandarino, 1975	74
117 A11/1	Old Crow–Babbage Depression	Cu, U, Mo, W	7	EMR, 1980a	76
117 A11/2	Barn Uplift	W, Mo	7	Norris, 1981d	78
117 A13/1	Romanzof Uplift	W, Cu, Mo	7	DIAND, 1993	58
117 A13/2	Romanzof Uplift	Au	7	Norris, 1981d	57
117 C1/1	Romanzof Uplift	Au	7	EMR, 1980b	55
Industrial Minerals					
106 M3/1	Northern Interior Platform	gvl	7	Duk-Rodkin and Hughes, 1992	97
106 M8/1	Northern Interior Platform	gvl	7	Harris et al., 1983	92
116 I7/1	Eagle Fold Belt	ss	7	Norris, 1981c	106
107 B2/1	Aklavik Arch Complex	ls	7	Norris, 1981b	68
107 B7/1	Aklavik Arch Complex	ls	7	Norris, 1981b	67
107 B7/2	Aklavik Arch Complex	dol	7	Norris, 1981b	66
Coal					
106 E2/2	Richardson Anticlinorium	C	2	DIAND, 1993	158
106 E3/3	Taiga–Nahoni Foldbelt	C	2	DIAND, 1993	161
106 E6/1	Bonnet Plume Basin	C	2	Norris and Hopkins, 1977	166
106 E6/2	Bonnet Plume Basin	C	2	Norris and Hopkins, 1977	165
106 E6/3	Richardson Anticlinorium	C	2	Norris and Hopkins, 1977	160
106 E7/1	Bonnet Plume Basin	C	2	DIAND, 1993	159
106 E11/1	Bonnet Plume Basin	C	2	DIAND, 1993	128
106 E14/1	Bonnet Plume Basin	C	2	Norris and Hopkins, 1977	125
106 E14/2	Bonnet Plume Basin	C	2	Norris and Hopkins, 1977	126
106 E14/5	Bonnet Plume Basin	C	2	DIAND, 1993	127
107 B4/2	Aklavik Arch Complex	C	7	Norris, 1981b	70
107 B11/1	Aklavik Arch Complex	C	7	Price et al., 1980	64
116 F5/1	Taiga–Nahoni Foldbelt	C	7	Norris, 1976	119
116 P15/1	Aklavik Arch Complex	C	7	Norris, 1974	85
117 A3/1	Old Crow–Babbage Depression	C	7	Norris, 1981d	82
117 A7/2	Rapid Depression	C	7	Cameron et al., 1986	81
117 A9/2	Aklavik Arch Complex	C	7	DIAND, 1993	61
117 A9/3	Rapid Depression	C	7	DIAND, 1993	60
117 A11/3	Old Crow–Babbage Depression	C	7	Norris, 1981d	77
117 A14/1	Rapid Depression	C	7	Norris, 1981d	59
117 C8/1	Romanzof Uplift	C	7	Cameron et al., 1986	53
117 C8/2	Romanzof Uplift	C	7	Cameron et al., 1986	54
117 C8/3	Romanzof Uplift	C	7	Cameron et al., 1986	52
117 D4/1	Romanzof Uplift	C	7	Cameron et al., 1986	56
Bitumen Intrusions					
106 E15/1	Richardson Anticlinorium	B	7	Stelck, 1944	123
106 E15/2	Richardson Anticlinorium	B	7	Stelck, 1944	124
106 N13/1	Northern Interior Platform	B	7	Norris and Cameron, 1986	87
Oil and Gas Seeps					
106 N4/1	Northern Interior Platform	G	7	Norris, 1981e	93
116 I6/1	Eagle Fold Belt	O	7	Norris, 1974	104
116 I6/2	Eagle Fold Belt	O	7	Norris, 1974	105

*Status Code of commodities follows definitions in EMR, 1980a, p 45. 2: Reserves, or demonstrated resources are reported or can be calculated but the commodity has not yet been produced. 7: Commodity reported, but insufficient data are available to allow status to be classified. Abbreviations: Ba, Barium; B, Bitumen; C, Coal; Cu, Copper; F, Fluorite; Au, Gold; Gp, Gypsum; Fe, Iron; Pb, Lead; Mo, Molybdenum; P, Phosphate; Ag, Silver; W, Tungsten; U, Uranium; Zn, Zinc.

Table 15.2

Distribution of commodity types among tectonic elements comprising the project area

COMMODITY TYPE / TECTONIC ELEMENT												Coal			
	Placer Au	Vein Zn, Pb, Cu	Skarn W, Cu, U, Mo	Sedimentary Fe	Carbonate-hosted Zn, Pb, Cu, Ba	U	P205	F	Gypsum	Barite	Hydrocarbons	Lignite	Sub-bituminous	Bituminous	Anthracitic
Beaufort Mackenzie Basin											●			●	
Rapid Depression			●	●		●	●							●	●
Romanzof Uplift	●														●
Old Crow-Babbage Depression		●	●									●			●
Barn Uplift			●			●									
Aklavik Arch Complex				●		●	●	●	●						●
Kandik Basin															
Taiga-Nahoni Fold Belt		●		●	●		●			●					●
Eagle Fold Belt											●				
Richardson Anticlinorium		●			●	●			●		●				
Bonnet Plume Basin												●	●	●	
Mackenzie Fold Belt				●	●				●						
Northern Interior Platform											●				

Aklavik Arch Complex

Metallic mineral occurrences within the Aklavik Arch Complex (Table 15.2) are few and far between, in spite of the complicated and protracted structural and stratigraphic history of the complex. In the northern Ogilvie Mountains close to the Alaska border, the "Salmon Fork" occurrence (116 K10/1) is goethite with significant zinc, nickel and copper, apparently hosted in undivided Carboniferous and Permian carbonate and clastic rocks (Norris, 1979, p. 103–104). It would appear to differ from the "Rusty Springs" locality (116 K9/2, discussed above) a few kilometres to the east, where the mineralization is reported in the Middle Devonian Ogilvie Formation. As far as is known, "Salmon Fork" is the first reported occurrence of base metals that may be hosted at the stratigraphic level of the upper Paleozoic in the northern Canadian Cordillera. Should the mineralization be strata bound, it could herald renewed and accelerated interest in the mineral potential of the Yukon Territory and adjacent Alaska because these rocks, at or near the edge of the upper Paleozoic carbonate shelf, are widespread in the Ogilvie Mountains.

On the northwest flank of the Aklavik Arch Complex in the vicinity of Mount Davies Gilbert (117 A8/2, 117 A8/3, "Delta Iron"; Fig. 15.1), a fine-grained, phosphatic quartz siderite unit occurs at the top of the late Early Cretaceous, flyschoid Rapid Creek Formation (Young and Robertson, 1984). According to Young and Robertson, the formation comprises thin to medium beds of sideritic phosphatic ironstone alternating with ferruginous, dark grey shale. It forms an immense low-grade iron deposit in the lower Big Fish River and Rapid Creek drainage, containing an estimated 100 billion tonnes of ferric oxide equivalent. A unique phosphate mineral assemblage (Sturman and Mandarino, 1975) occurring in fractures produced by Laramide folding of the formation is associated with the iron deposit.

Minor mineral occurrences in the northern Richardson Mountains include copper sulphides reported to be associated with a dyke in "Jurassic" country rock on Mount Goodenough (106 M13/1; EMR, 1980a), and gypsum extruding along the Donna River Fault (107 B4/1, 107 B5/1; Norris, 1981b).

Rapid Depression

The "Delta Iron" deposit (Rapid Creek Formation) extends into the depression from the northwest flank of Aklavik Arch Complex. It is exposed along Rapid Creek at localities 117 A8/1 and 117 A9/1 on the east flank of the depression. Moreover, it may outcrop axially in the depression in the Blow River drainage because lazulite, one of the phosphate minerals associated with the sideritic iron in the Aklavik Arch Complex, was first recovered there as float (Young and Robertson, 1984).

Close to the west flank of the depression at Mount Fitton, molybdenum, tungsten, and uranium mineralization occurs in skarn zones associated with Devonian hornblende biotite granite (117 A7/1; EMR, 1980a; Sinclair, 1983). The granite is hosted in the lower Paleozoic Road River Formation. Scheelite with minor gold and molybdenite occurs as placers in streams draining the area (EMR, 1980a).

Minor radioactive chert in fractures in rudaceous rocks of the Road River Formation has been reported (EMR, 1980a) in the upper reaches of the Rapid Depression at the headwaters of the Driftwood River and Johnson Creek (117 A2/1, 116 O16/1).

Barn Uplift

A biotite granite in the northeast corner of the Barn Uplift at the headwaters of Fitton Creek is named the Hoidahl Cupola (Norris, 1981d) after its discoverer Anker Hoidahl, a pioneer prospector of Yukon's north slope. Associated with the intrusion is a skarn zone (117 A11/2) enriched with tungsten, copper, uranium and molybdenum (EMR, 1980a), similar to that observed on Mount Fitton a few kilometres to the southeast. Like the Mount Fitton occurrence, the host rock is the lower Paleozoic Road River Formation comprising the core of the uplift. Uranium and phosphate mineralization has been reported from silicified breccias within Road River equivalent and Endicott Group rocks on the south flank of the uplift (DIAND, 1993).

Old Crow-Babbage Depression

Immediately north of the Barn Uplift near the northeast extremity of the Old Crow-Babbage Depression, an occurrence of copper, uranium, molybdenum and tungsten mineralization (117 A11/1) is reported (EMR, 1980a) in calcareous shale. Its geographic coordinates suggest that it is also hosted in the Road River Formation. It is in an inlier surrounded by the Jura-Cretaceous Kingak Formation.

Lead, zinc and tungsten mineralization is reported from the south flank of the Late Devonian or Early Carboniferous Old Crow Batholith. There, galena and sphalerite have been found in float associated with the intrusion (116 N10/2) and as much as 0.08 per cent tin is associated with copper-rich skarn zones (Sinclair, 1983). Scheelite is reported from placers (e.g., 116 N10/1) in streams draining the batholith (EMR, 1980a).

Romanzof Uplift

At the southeast extremity of the uplift, disseminated chalcopyrite and molybdenite is reported (Bell and Jones, 1979) in a sericitized zone (117 A13/1) within biotite hornblende granite of the Late Devonian or Early Carboniferous Mount Sedgwick Stock. The host rock is probably the lower Paleozoic Road River Formation, as at 117 A11/1, 117 A11/2 and 117 A7/1 in and around the Barn Uplift. Scheelite placers are known (EMR, 1980a) in streams draining the area of the Mount Sedgwick Stock (117 A13/1) and placer gold has been discovered (A. Hoidahl, pers. comm., 1961) on "Schist" and "Prospect" creeks (informal names used by Hoidahl), for two small creeks (117 A13/2) draining the northwest flank of Mount Sedgwick into Crow River.

On "Schist" and "Prospect" creeks, at the contact of the granite with slaty argillites and quartzites of the Road River(?) Formation, Findlay et al. (1986) identified a target area for base metals, uranium, silver, tungsten and gold, among other elements. Although they note no surface reflection of the contact zone, a mineral occurrence of uranium is indicated (sample no. 82-168) in the skarn zone at the headwaters of "Prospect" Creek.

Placer gold has been recovered from bars in the Firth River since at least the turn of the last century (Sandy, 1948) but there are few, if any, authenticated records of the amount of gold recovered. By far the greatest production is reported from Sheep Creek (117 C1/1), a western tributary of the Firth River, close to the crown of the Romanzof Uplift. The free gold appears to occur in the unglaciated surficial deposits on the pediments flanking the Firth River valley. It may have become trapped through solifluction in layer-parallel separations between upturned beds of the Neruokpuk and Road River formations and, in turn, concentrated in the gravel of the creek as the bedrock was worn away. The ultimate source for the gold is unknown, but its occurrence as flakes and usually small, well-worn, flattened grains about the size of rolled oats (EMR, 1980b) suggests that it travelled far. If it was reworked from the Neruokpuk sedimentary succession, the gold would have to be Precambrian in age and its ultimate source may have been a great distance from the Romanzof Uplift. On the other hand, Devonian granitic intrusions at the headwaters of the Firth River in Alaska lend credence to the possibility that they were the ultimate source, that the gold in the Firth River drainage is Devonian in age, that it was weathered out of the intrusions and was carried down the pediplains in the Holocene to be trapped in the natural riffles formed by upturned beds of the Neruokpuk and Road River formations. Similarly, gold in the Trail and Crow River drainages may have come from the Devonian Sedgwick and Fitton stocks.

CONSTRUCTION MATERIALS

As an integral part of the assessment of the mineral potential of the project area, Hughes, with the assistance of V.N. Rampton, prepared photo-interpretive maps of the surficial geology at a scale of 1:125 000 and compiled and published them at a scale of 1:500 000 (Hughes, 1972; GSC Map 1319A). More recent, larger scale maps, where they are available, provide detailed information on the location and distribution of construction materials (Duk-Rodkin and Hughes, 1991; Hughes and Pilon, 1973; Rampton, 1982, 1988; Thomas and Rampton, 1982a, b, c).

The principal construction materials in the project area are sand, gravel and crushed rock, used extensively in the building of the Dempster Highway, the connecting link between Inuvik, Northwest Territories, and Dawson City, Yukon, on the Klondike Highway (Fig. 15.1). The large number of borrow pits scattered throughout the length of the highway attest to the exploitation of this resource. Not only have the pits provided building materials in close proximity to their point of use, but also they have provided access to bedrock in areas where exposures are nonexistent, poor or otherwise inaccessible. In some instances in the Eagle Plain, Peel Plateau and Peel Plain, for example, they have provided priceless stratigraphic control for regional mapping.

Aggregate

The largest sources of aggregate (sand and gravel) in the project area are glaciofluvial deposits formed during the retreat of the Laurentide Ice Sheet, and during the retreat of montane glaciers that occupied the larger valleys of the Mackenzie and Ogilvie Mountains (Fig. 15.2). These deposits are very unevenly distributed. They are lacking, of course, in the approximately 50 per cent of the area that lies within the unglaciated Beringian Refugium. Within the glaciated area, perhaps 45 per cent of the glaciofluvial deposits are concentrated in the Bonnet Plume Depression, whereas broad expanses in the Peel Plain and northwestern Anderson Plain are devoid of or are deficient in glaciofluvial deposits. The deficiency is exacerbated in the latter two areas because they are underlain mainly by shales and siltstones of the Upper Devonian Imperial Formation and the Lower Cretaceous Arctic Red and Horton River formations that are unsuitable for crushing to produce aggregate.

The quality of material in the glaciofluvial deposits is variable. Moderate to large size glaciofluvial plains, most of which are associated with major meltwater channels, consist dominantly of well sorted gravel; two large outwash plains near the Tree River in the Peel Plain, that comprise mostly sand, are known exceptions. Extensive glaciofluvial deposits in the Tuktoyaktuk Peninsula are likewise dominantly sand (Rampton, 1988). Smaller deposits, in the form of kames and eskers, may vary widely from silty sand to boulder gravel within a single occurrence.

Alluvial (fluviatile) deposits that form the flood plains and terraces of the modern streams in both the glaciated and unglaciated parts of the project area are additional sources of aggregate. They vary greatly depending on the energy level of the particular stream and the substrate on which they are developed.

High energy streams such as the Cranswick, Snake, Bonnet Plume and Wind rivers that emanate from the glaciated Mackenzie Mountains have dominantly gravelly alluvium. In the upper reaches of the Peel and Arctic Red rivers, point bars comprise mainly gravel, and flood plains and terraces comprise mainly gravel with a cover of 1 to 2 m of silty overbank sediments. However, because post-glacial eustatic rise of sea level with respect to the land has reduced stream gradients, the alluvial sediments in the lower reaches of those rivers are mainly silt and fine grained sand. The lower reaches of the Caribou, Trail, Road and Vittrekwa rivers have mainly gravelly alluvium, but because these streams are deeply incised into Cretaceous shale and siltstone, the gravel may contain too many weak clasts for uses such as concrete aggregate.

In the unglaciated area, the Porcupine River and most of its tributaries have flood plains and terraces of gravel with 1 to 2 m of overbank silt and sand. The Old Crow River is a notable exception. Above the Old Crow Canyon, where that stream exits from the Old Crow Basin, it is incised into Quaternary sediments that are almost wholly lacking in gravel, and accordingly, the alluvial deposits consist mainly of sand and silt.

The extraction of gravel from flood plains can result in stream siltation that can be harmful to fish and other aquatic organisms. Exploitation of gravel from terraces that are clearly above flood level is, therefore, preferable to exploitation of flood plain gravel.

Beaches associated with a glacial lake that inundated the Bell, Bluefish and Old Crow basins afford restricted aggregate supplies. Materials of the beaches, best developed around the periphery of the Old Crow Basin, range from sand to very coarse boulder gravel. A spit that extends westward from the north end of Schaeffer Mountain constitutes a very large source of good quality gravel.

Gravel of Tertiary age constitutes another minor source of aggregate. It is found on high terraces along the Bell River between the mouth of the Eagle River and the west end of McDougall Pass. The terrace system extends through the pass, but as bedrock benches from which the gravel has been removed by glacial erosion. Tertiary gravel also forms a capping on a mesa known informally as ''Airport Hill'' (106 M3/1) north of the Dempster Highway, 47 km east of the boundary between Yukon and Northwest Territories.

Gravel supplies at Inuvik have been exhausted. Aggregate is now supplied by crushing limestone of the Lower and Middle Devonian Ogilvie Formation at one quarry north of Campbell Lake (107 B7/1) and another east of the lake (107 B2/1; Fig. 15.1). Crushed aggregate has also been used extensively as road metal on the Dempster Highway. One crushed product from siliceous argillite of the Canol Formation, used on the west flank of the Richardson Mountains, proved to be very damaging to tires.

Other construction materials

The entire area lies within the continuous and discontinuous permafrost zones. Except for gravel, all of the surficial materials contain low to very high contents of segregated ice, resulting in varying degrees of subsidence and slope instability where protective vegetation and/or cover are removed, allowing the material to thaw. This has led to the adoption of passive construction methods that maintain the thermal regime of the soil. The simplest of the passive construction modes is the use of thick pads of aggregate or common fill as foundations for buildings, airstrips and highways. Gravel is the only surficial material suitable for pad construction, but in most areas reserves are limited and should be retained for higher uses. Experience in construction of the Dempster Highway showed that shale and siltstone of the Imperial, Arctic Red and Horton River formations are essentially free of segregated ice and are suitable for pad construction. Proterozoic argillite, quartzite and dolomite (107 B7/2) were quarried for construction of the runways at Inuvik Airport.

Large blocks for use as rip-rap can be quarried from any of the carbonate or quartzite formations in the area. Unfortunately, suitable sources are lacking in most of the Peel and Anderson plains.

COAL

A wide variety of ranks, qualities and ages of coal occurs in the project area of northern Yukon Territory and western District of Mackenzie. They are contained in structural depressions and uplifts, and some are acutely deformed whereas others are not (Fig. 15.1). As a general rule, all Early Cretaceous and older coals are anthracitic, whereas all Late Cretaceous and Tertiary coals are high volatile bituminous to lignitic.

Bonnet Plume Basin

Bonnet Plume Basin, a structurally controlled intermontane feature resting asymmetrically on the west flank of the Richardson Anticlinorium (Norris and Hopkins, 1977), contains some of the thickest and areally extensive coal seams. Along the south bank of the Peel River, between the Wind and Bonnet Plume rivers, Mountjoy (1967) reported three lignite seams greater than 1.5 m thick (106 E14/1, 106 E14/2) in the Maastrichtian to Eocene part of the section. There may be more than one billion tonnes of lignite underlying the northern one half of the basin. On the south flank of the basin, moreover, the Upper Cretaceous Cenomanian to Maastrichtian section (106 E6/1, 106 E6/2, etc.) has been extensively drilled by Pan Ocean Oil Ltd. and Mountaineer Mines Ltd. There, about 200 million tonnes of subbituminous to high volatile bituminous coal have been outlined as inferred resources (Smith, 1989, p. 102). None of these coals may be of economic value at this time but, should the exploitation of the Snake River iron deposit (106 F1/1 etc.) go ahead, they may be invaluable as a source of thermoelectric power for beneficiation of the ore.

Aklavik Arch Complex

Paleocene coals of the Aklak Member of the Reindeer Formation occur in the Big Fish River drainage on the northwest flank of Aklavik Arch Complex. One seam, including partings, is 7 m thick. The coals are subbituminous to high volatile bituminous like those in the southern Bonnet Plume Basin. For the most part they are contained in a gently seaward-dipping panel of Upper Cretaceous and lower Tertiary nonmarine and marine rocks. At Coal Mine Lake (117 A9/2), where they have been mined in the northwest extremity of Mackenzie Delta, however, the seams are vertical because of early Tertiary (Eocene?) compression in the late stages of the Laramide Orogeny.

On the crest of the Aklavik Arch Complex, several thin anthracitic coal seams occur in the Lower Cretaceous Kamik Formation at the headwaters of the Bell River (Norris, 1974, p. 348). There, on the north bank of a small, unnamed tributary from the west to the Bell River (116 P15/1), seams up to 0.3 m thick and with 6 per cent ash occur in an acutely folded succession. They would appear to be of little immediate economic value because of their remote location. Coeval seams in the Kamik on the east flank of the Aklavik Range (107 B4/2), however, are accessible from the town of Aklavik in the Mackenzie Delta, and could be exploited for domestic use.

In the Caribou Hills on the east flank of the Mackenzie Delta, the Paleocene-Eocene Reindeer Formation contains several lignite seams scattered throughout the formation (107 B11/1; Price et al., 1980). Bocannes from them may be seen at numerous places along the southwest face of the hills. Although beside the East Channel of the Mackenzie River and hence readily accessible, the lignite has not been exploited systematically, even for local use.

Rapid Depression

In the Rapid Depression, high quality Carboniferous coals in the lower part of the Mississippian Kayak Formation, are anthracitic. They have been examined on the south and southeast flanks of the Hoidahl Dome (117 A7/2). There, one of the seams, with a measured thickness of about 5.5 m, has an average ash content of less than 7 per cent and sulphur content of about 0.5 per cent. It is a prospective source of good thermal coal (Cameron et al., 1986). The coal-bearing part of the Kayak Formation has been traced and sampled for about 4 km along strike and shows promise of more than one thick seam of high quality coal with considerable lateral extent on the south flank of the dome (Cameron et al., 1988).

Poor quality, high volatile bituminous coal of the Paleocene Aklak Member of the Reindeer Formation is exposed on the west flank of the Deep Creek Syncline (Norris, 1981d). There (117 A14/1), a 2 m seam is interbedded with fine to coarse clastics (Norris, 1972) coeval with the coal-bearing Aklak Member at Coal Mine Lake.

Romanzof Uplift

In the extreme northwest corner of the project area, the Mississippian Kayak Formation is extensively exposed in the cores of folds and in structurally depressed blocks (117 C8/1, 117 C8/2, 117 C8/3, 117 D4/1; Norris, 1981f). All coal seams sampled were much less than 1 m thick. All were anthracitic and much higher in ash content than the 5 m seam discussed above in the Hoidahl Dome. They would appear to be of little economic importance.

Old Crow-Babbage Depression

On the northwest flank of the Barn Uplift (117 A11/3) in the Babbage Depression, the Kayak Formation has at least one seam of bright, anthracitic coal containing 12 per cent ash. Float from this or other seams on the west and south flanks of the uplift would indicate that the coal measures are widespread in the Kayak, although no outcrops of the seams have been reported there.

At the headwaters of Johnson Creek (117 A3/1), approximately 12 m of flat-lying lignite occurs in two zones interlayered with white bentonite. The coal is very immature, with random reflectances ranging from 0.15 to 0.20 (Cameron and Norris, 1987). The lower zone is 3 m thick and the upper one is 7 m thick. The succession is Oligocene in age (Norris, 1981d) and appears to be localized in a topographic depression on a pre-Oligocene erosion surface in the eastern Old Crow-Babbage Depression. It would appear to be coeval with the Oligocene(?) "white-clay unit" (Price et al., 1980) between the Reindeer and Beaufort(?) formations in the Caribou Hills east of the Mackenzie Delta, and with the Kugmallit Sequence offshore (G. Morrell, pers. comm., 1991).

Taiga-Nahoni Foldbelt

In the Nahoni Range in the southwest corner of the project area, the Lower Cretaceous Kamik Formation is coal-bearing. There (116 F5/1), a poorly exposed and deeply oxidized seam of anthracite has been sampled in GSC section 116F14 (Norris, 1982c).

OIL AND GAS

The hydrocarbon potential of the project area appears to be confined largely to the Eagle Foldbelt in the south and to the Beaufort–Mackenzie Basin and the Aklavik Arch Complex in the north. There are, however, widely scattered hydrocarbon showings in the form of bitumen intrusions and oil and gas seeps in the northern Interior Platform, Richardson Anticlinorium and Eagle Foldbelt. The intrusions and seeps may or may not be of commercial significance but their known occurrences are reported here for completeness. The oil and gas plays, on the other hand, are dealt with in some detail.

Hydrocarbon source rocks in the project area and adjacent continental shelf may range in age from Late Devonian to mid-Tertiary. Principal sources, however, appear to be confined to the Upper Devonian, Lower Carboniferous, Jura-Cretaceous, Upper Cretaceous and lower Tertiary.

In the Eagle Foldbelt, the black, petroliferous Upper Devonian and Lower Carboniferous Ford Lake Shale appears to be the logical source for the gas and oil in the Chance Field. Oil and gas seeps in the Interior Platform, on the other hand, may well have their source in the Upper Devonian Canol Formation (Norris and Cameron, 1986). The latter may also prove to be a source for gas trapped beneath thick, flyschoid clastics of the Kandik Basin along the international boundary with Alaska.

Source rocks in the lower Mackenzie River and offshore areas are found in two main intervals (Campbell, 1990, p. 10; Fig. 15.3). Offshore, the source for the bulk of the Tertiary oil and gas discoveries is believed to be the Eocene Richards shale which is generally undermature. Onshore, the recognized source rocks are the organic rich, thermally mature Upper Cretaceous Smoking Hills and Boundary Creek formations, and possibly the Jura-Cretaceous Husky Formation (Campbell, op. cit.).

Interpretation of maturation levels (Link and Bustin, 1989; Link et al., 1989) onshore in the project area suggests that maturation increases with structural complexity, probably as a result of high paleoheat flow associated with tectonism and concomitant deep burial. Organic maturity is generally highest in the structurally positive tectonic elements and lowest in the negative ones. Thus, coeval strata can range from immature to overmature with respect to the oil window from one tectonic element to another. Strata have generally lower maturity in the Northern Interior Platform and Eagle Foldbelt than in the Richardson Anticlinorium, Taiga–Nahoni Foldbelt and Aklavik Arch Complex.

Bitumen intrusions

Three bitumen intrusions are known within the project area, two in the Richardson Anticlinorium and one in the Northern Interior Platform (Fig. 15.1). They are reported here (Table 15.1) insofar as they are encouraging signs of trapped hydrocarbons at depth.

Richardson Anticlinorium

Two bitumen (albertite?) dykes were discovered by Stelck (1944) on Peel River between Bonnet Plume and Snake Rivers (106 E15/1, 106 E15/2). They were observed to be hosted in a resistant sandstone bed (Mississippian Ford Lake Formation) that is folded into the gentle, northwest-trending Toltec Anticline on the east flank of the Richardson Anticlinorium. Petroliferous Upper Devonian shale, reported by Stelck (op. cit.) in the riverbanks around the anticline in association with the dykes, instigated the drilling of the Toltec Peel River YT N-77 well in 1968. It was abandoned because of mechanical failure at a depth of 1123 m.

Northern Interior Platform

A spectacular sill-like mass of solid bitumen is exposed in a borrow pit on the Dempster Highway, 7 km north of the Rengleng River (106 N13/1). It is hosted in the gently folded, Upper Devonian Imperial Formation. The reflectance of the bitumen suggests a maturity level well within the "oil window" and is a positive sign for hydrocarbons at depth within Middle Devonian and older formations comprising the Northern Interior Platform (Norris and Cameron, 1986). Bitumen has been reported (Pugh, 1983, fig. 35) from these rocks in several boreholes.

Oil and gas seeps

Like the bitumen occurrences, oil and gas seeps are encouraging signs for the localization of hydrocarbons at depth. Three examples are known within the project area, two in the Eagle Foldbelt and one in the Northern Interior Platform (Fig. 15.1; Table 15.1).

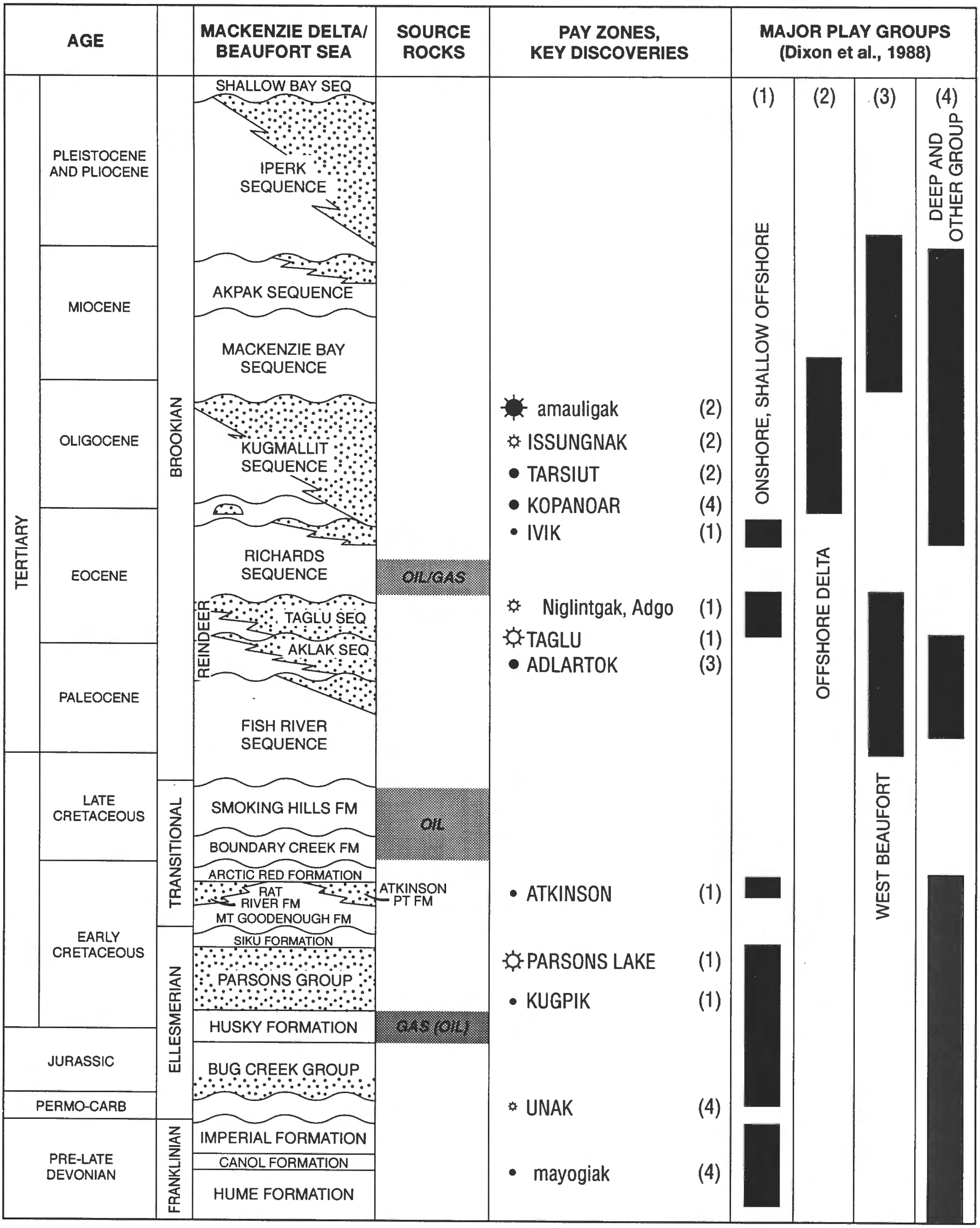

Figure 15.3. *Stratigraphic succession, important reservoirs and major hydrocarbon play groups in the Mackenzie Delta–southern Beaufort Sea region (after Campbell, 1990, fig. 2, with permission). Numbers in parentheses identify key discoveries with play groups.*

Eagle Foldbelt

On a north-flowing, unnamed western tributary of the Eagle River is an outcrop of Upper Devonian shale (116 I6/1; Norris, 1981c) with septarian, ironstone nodules rich in fossil hash and saturated with natural aromatic hydrocarbons (Norris, 1974, p. 348). This, in conjunction with a porous, oil-saturated, ridge-forming sandstone at the base of the Upper Cretaceous Eagle Plain Formation 6 km to the southwest (116 I6/2; Norris, 1981c), is a strong indication of oil and gas seeping from reservoirs at depth. Indeed, the Chance oil and gas field is only 35 km to the southwest.

Northern Interior Platform

A strongly flowing gas seep (106 N4/1), with an estimated flow rate of 700 cf/d, is reported west of the Arctic Red River in northern Swan Lake (Norris, 1968; Norris, 1981e; Lichtenbelt, J.H. *in* Pugh, 1983, fig. 35). The surface rocks are Upper Devonian Imperial Formation and the flow is doubtless coming from Middle Devonian and older Paleozoic carbonate rocks of the platform.

Oil and gas plays

As might be anticipated from the variety of tectonic elements making up the project area (Fig. 15.1), there is a diversity of ages and styles of the associated structural and stratigraphic traps. In the Eagle Foldbelt, for example, Late Cretaceous or early Tertiary buckle folds dominate as the trapping mode. In the Mackenzie Delta, Tuktoyaktuk Peninsula and eastern Beaufort Sea, rollover anticlines associated with extension faults, culminations in the hanging-wall of rotated fault blocks and Cenozoic shale-cored anticlines predominate. In the western Beaufort Sea, on the other hand, mid-Tertiary buckle folds with amplitudes and wavelengths similar to those in the Eagle Foldbelt are prevalent.

Of the 29 wells drilled in the Eagle Plain, three are discovery wells. Onshore, in the Mackenzie Delta–Tuktoyaktuk Peninsula region, a total of 159 wells have been drilled and 25 of them are significant discoveries. Offshore, 91 wells resulted in 27 discoveries (G.R. Campbell, pers. comm., 1991). The tally for the project area, therefore, is 55 significant oil and gas discoveries among 279 wells. The discoveries, with supporting data, are listed in Table 15.3 and the play groups embracing them are illustrated in Figure 15.3. For those wells in the Mackenzie Delta–Beaufort Sea region, as a generalization, the age of the reservoir rocks decreases progressively from on- to offshore (Fig. 15.1). In the Parsons Lake Field, the reservoirs are in the Lower Cretaceous Parsons Group (KP and KKa); farther north at Taglu they are in the lower Tertiary Reindeer Formation (TR) and Taglu Sequence (TTa); medially on the continental shelf they are in the mid-Tertiary Kugmallit deltaic (TKg) and deep-water (TKp) sediments; and on the outer edge of the shelf they are in the late Tertiary Mackenzie Bay (TMB) and Akpak (TAk) sequences.

The structural and tectonic setting of these hydrocarbon-bearing regions within the project area will now be discussed and illustrated with selected examples of potential plays. It is recognized that other circumstances, such as the carbonate-shale transitions on the flanks of Richardson Trough, are prospective. Thus far, however, no significant oil or gas discoveries have been made within them and they will not be discussed further.

Eagle Foldbelt

In the western two thirds of Eagle Foldbelt, the Cretaceous Eagle Plain Group is at the surface. It is folded into gentle, moderately plunging, north-trending anticlines and synclines whose axial surfaces can in some instances be traced up to 120 km along strike. Many lie in *en echelon* arrays. Their curviplanar axial surfaces are commonly vertical to steeply westward-verging. In the eastern one third of the foldbelt, on the other hand, middle and upper Paleozoic sedimentary rocks predominate at the surface. They are also folded on north trends, parallel to the structural grain of the Richardson Anticlinorium to the east and to folds in the Eagle Plain Group.

The Devonian and younger Paleozoic rocks in the Eagle Foldbelt are overlain with regionally angular unconformity by Albian and younger strata of the Eagle Plain Group (Norris, 1981c, 1982c). They dip gently southward and are truncated primarily by pre-Albian erosion so that progressively older formations lie beneath the unconformity from south to north. Stratigraphic trends are from east to west.

The structure, observed at the surface in middle and upper Paleozoic rocks of the eastern one third of the foldbelt, moreover, is presumed to continue westward beneath this unconformity. The whole stratigraphic succession, including the unconformity, was folded in the Late Cretaceous or early Tertiary. Potential Carboniferous and Permian reservoir rocks occur in favourable trapping configurations at updip pinchouts,

Table 15.3

Significant oil and gas discoveries in the project area listed in order of discovery between May, 1960 and March, 1991. Information on each well includes the principal commodity, its reservoir(s) and tectonic setting. Data for the Beaufort Sea–Mackenzie Delta region are after Campbell (1990) and Morrell (pers. comm., 1990)

Well	Tectonic element	Commodity	Principal reservoir(s)	Locality no.
Chance No. 1	Eagle Foldbelt	oil and gas	Hart River (CHR)	114
Blackie YT M–59	Eagle Foldbelt	gas	Jungle Creek (PJC)	113
Birch YT B–34	Eagle Foldbelt	gas	Hart River (CHR)	112
Atkinson H–25	Aklavik Arch Complex	oil	Atkinson Pt. (KAP)	29
Taglu G–33	Beaufort–Mackenzie Basin	gas	Reindeer (TR)	43
Mayogiak J–17	Aklavik Arch Complex	oil	Landry (DL)	30
Parsons F–09	Aklavik Arch Complex	gas	Kamik (KKa)	50
Ivik J–26	Beaufort–Mackenzie Basin	oil	Richards (TRi)	35
Mallik A–06	Beaufort–Mackenzie Basin	gas	Kugmallit (TKg)	37
Titalik K–26	Beaufort–Mackenzie Basin	gas	Taglu (TTa)	48
Niglintgak H–30	Beaufort–Mackenzie Basin	gas	Reindeer (TR)	42
Ya Ya P–53	Beaufort–Mackenzie Basin	gas	Taglu (TTa)	47
Reindeer F–36	Beaufort–Mackenzie Basin	gas	Reindeer (TR)	49
Kugpik O–13	Aklavik Arch Complex	oil	Kamik (KKa)	62
Ivik K–54	Beaufort–Mackenzie Basin	oil	Richards (TRi)	36
Kumak J–06	Beaufort–Mackenzie Basin	oil and gas	Taglu (TTa)	44
Adgo F–28	Beaufort–Mackenzie Basin	oil and gas	Taglu (TTa)	39
Ya Ya A–28	Beaufort–Mackenzie Basin	gas	Taglu (TTa)	46
Pelly B–35	Beaufort–Mackenzie Basin	gas	Kugmallit (Kg)	38
Imnak J–29	Aklavik Arch Complex	oil	Mount Goodenough (KMG)	33
Garry P–04	Beaufort–Mackenzie Basin	dry and abandoned	Reindeer (TR)	41
Netserk F–40	Beaufort–Mackenzie Basin	gas	Kugmallit (TKg)?	25
Kamik D–48	Aklavik Arch Complex	oil	Kamik (KKa)	51
Nektoralik K–59	Beaufort–Mackenzie Basin	oil and gas	Mackenzie Bay (TMB)	2
Kopanoar M–13	Beaufort–Mackenzie Basin	oil and gas	Kugmallit (deep-water) (TKp)	3
Ukalerk C–50	Beaufort–Mackenzie Basin	gas	Kugmallit (TKg)	7
Nerlerk M–98	Beaufort–Mackenzie Basin	oil	Kugmallit (TKg)	4
Isserk E–27	Beaufort–Mackenzie Basin	gas	Kugmallit (Tkg)	14
Garry G–07	Beaufort–Mackenzie Basin	gas	Reindeer (TR)	40
Tarsiut A–25	Beaufort–Mackenzie Basin	oil and gas	Kugmallit (TKg)	18
Kenalooak J–94	Beaufort–Mackenzie Basin	gas	Kugmallit (deep-water) (TKp)	1
Koakoak O–22	Beaufort–Mackenzie Basin	oil and gas	Kugmallit (deep-water) (TKp)	5
Issungnak O–61	Beaufort–Mackenzie Basin	oil and gas	Kugmallit (TKg)	11
W. Atkinson L–17	Aklavik Arch Complex	oil	Ronning (OSR)	28
Kiggavik A–43	Beaufort–Mackenzie Basin	gas	Kugmallit (TKg)	20
Itiyok I–27	Beaufort–Mackenzie Basin	oil and gas	Kugmallit (TKg)	13
Havik B–41	Beaufort–Mackenzie Basin	oil and gas	Kugmallit (TKg)	6
Pitsiulak A–05	Beaufort–Mackenzie Basin	oil	Kugmallit (TKg)	16
Kadluk O–07	Beaufort–Mackenzie Basin	dry and abandoned	Kugmallit (TKg)	24
Amauligak J–44	Beaufort–Mackenzie Basin	oil and gas	Kugmallit (TKg)	10
Tuk L–09	Aklavik Arch Complex	gas	Kamik (KKa)	31
Amerk O–09	Beaufort–Mackenzie Basin	gas	Kugmallit (TKg)	27
Nipterk L–19	Beaufort–Mackenzie Basin	oil and gas	Kugmallit (TKg)	21
Tuk J–29	Beaufort–Mackenzie Basin	oil and gas	Taglu? (TTa?)	32
Adlartok P–09	Beaufort–Mackenzie Basin	oil	Aklak (TAk)	22
Minuk I–53	Beaufort–Mackenzie Basin	gas	Kugmallit (TKg) and Taglu (TTa)	23
Amauligak I–65A	Beaufort–Mackenzie Basin	oil and gas	Kugmallit (TKg)	9
Hansen G–07	Beaufort–Mackenzie Basin	oil and gas	Kugmallit (TKg) and Richards (TRi)	34
Ikhil K–35	Beaufort–Mackenzie Basin	gas	Taglu (TTa)	65
Arnak K–06	Beaufort–Mackenzie Basin	oil and gas	Richards (TRi)	27
Unak L–28	Aklavik Arch Complex	gas	Rat River (KRR) and Lisburne (CL)	63
Amauligak O–86	Beaufort–Mackenzie Basin	oil and gas	Kugmallit (TKg)	8
Nipterk P–32	Beaufort–Mackenzie Basin	oil and gas	Kugmallit (TKg)	26
Isserk I–15	Beaufort–Mackenzie Basin	oil and gas	Kugmallit (TKg)?	15
Unipkat N–12	Beaufort–Mackenzie Basin	oil and gas	Taglu (TTa)?	45

facies barriers and at the updip seal with Albian and younger strata. They are bounded by or lie in close stratigraphic proximity to potential source rocks like the Upper Devonian and Lower Carboniferous black shales with oil-saturated concretions (see 116 I6/1, above) of the Ford Lake Formation.

The Chance Gas Field, in the southern part of the Eagle Plain, is in these trapping configurations in both Carboniferous and Permian rocks. The Chance Sandstone Member of the Lower Carboniferous Hart River Formation is thus far the most important reservoir, followed by the Permian Jungle Creek Formation and basinal sandstones of the Hart River Formation (Graham, 1973, p. 179). Of 11 wells drilled in the southern Eagle Foldbelt up to 1968, three were significant discoveries in these reservoirs. Oil and gas are trapped in commercial quantities in the Chance Sandstone in Chance and Daglish anticlines and gas has been found in the Jungle Creek Formation in an unnamed anticline in the southeast corner of the foldbelt (Fig. 15.1; Table 15.3). Approximate reserves for the area total up to 2.8 x $10^9 m^3$ gas and 3.1 x $10^6 m^3$ oil (T. Bird *in* Hamblin, 1990).

Mackenzie Delta–Tuktoyaktuk Peninsula

The regional dip of the near-surface Mesozoic and Cenozoic formations in the Mackenzie Delta–Tuktoyaktuk Peninsula is gently to the northwest so that the stratigraphic succession embracing the bulk of the significant oil and gas discoveries thickens from an erosional zero edge against the Campbell Uplift (Dyke, 1975) to 12 km under Richards Island at the edge of the southern Beaufort Sea (Cook et al., 1987).

The Taglu Gas Field, on the Mackenzie Delta, lies in the Beaufort–Mackenzie Basin, on the northwest flank of the Aklavik Arch Complex. It was discovered in 1971 by seismic reflection surveys. The discovery well, IOE Taglu G–33, encountered gas in the lower Tertiary Reindeer Formation at a depth of 2490 m. Like the Parsons Lake Field, the structure has no surface expression. The hydrocarbons are trapped in a drag anticline in the immediate footwall of a major, down-to-basin, listric extension fault (Fig. 15.4a, after Campbell, 1990). The fault is one of a family that trends east, subperpendicular to Eskimo Lakes Fault Zone, and terminates against it. It parallels the Tarsiut–Amauligak trend offshore and juxtaposes Reindeer reservoir sandstones against shale of the Eocene Richards Formation. The latter could serve as source as well as seal for the gas.

Taglu is the largest onshore gas discovery in the region, containing 3.1 TCF of gas with some condensate (Campbell, op. cit.).

In the Tuktoyaktuk Peninsula, the Parsons Lake Gas Field (Fig. 15.4b) lies adjacent to the Aklavik Arch Complex, within the Eskimo Lakes Fault Zone (Norris, 1985, p. 800) at a depth of about 2700 m. The structural geometry of the field is that of a series of rollover anticlinal closures separated from one another by northeast-trending, listric extension faults of the Eskimo Lakes Fault Zone. The field, therefore, is elongate to the northeast and the closures between faults step down systematically in the direction of the Holocene continental shelf (Campbell, 1990). Stratigraphic thickening of the Jurassic and Lower Cretaceous formations across some of the faults document syndepositional displacements on curviplanar surfaces with their northwest walls lowered in the direction of the shelf. Reversals in dip because of this listric extensional displacement on reactivated strands of the fault zone are responsible for trapping the gas and oil in the field.

Gas was discovered at Parsons Lake in 1972 by seismic and gravity surveys that outlined an anticlinal closure at depth. The reservoir was found to be porous quartz arenites of the Lower Cretaceous Parsons Group (Coté et al., 1975). The thick succession of dark, marine shales overlying the reservoir (Lower Cretaceous Mount Goodenough Formation) forms the seal. These shales are considered potential source beds by some authors (Coté et al., 1975), whereas others (e.g., Langhus, 1980) consider the source beds to be thermally mature shales of the underlying Jurassic Husky Formation buried basinward of the field.

Since 1972 when the field was discovered, step-out drilling has indicated that there are 1.8 TCF of recoverable gas with some condensate in two main pools (Campbell, 1990, p. 12). These pools are named Parsons Lake (North) and Parsons Lake (South).

Offshore oil and gas discoveries

In the eastern part of the Beaufort–Mackenzie Basin, the reservoirs in which discoveries have been made are characterized by listric extension faults with associated rollover anticlines. In the western part, on the other hand, buckle anticlines predominate (Lane and Dietrich, in press). Between is a large area of overlap in which both extensional and compressional structures occur (G. Morrell, pers. comm., 1991). The folds and associated northeast-directed thrusts in the western

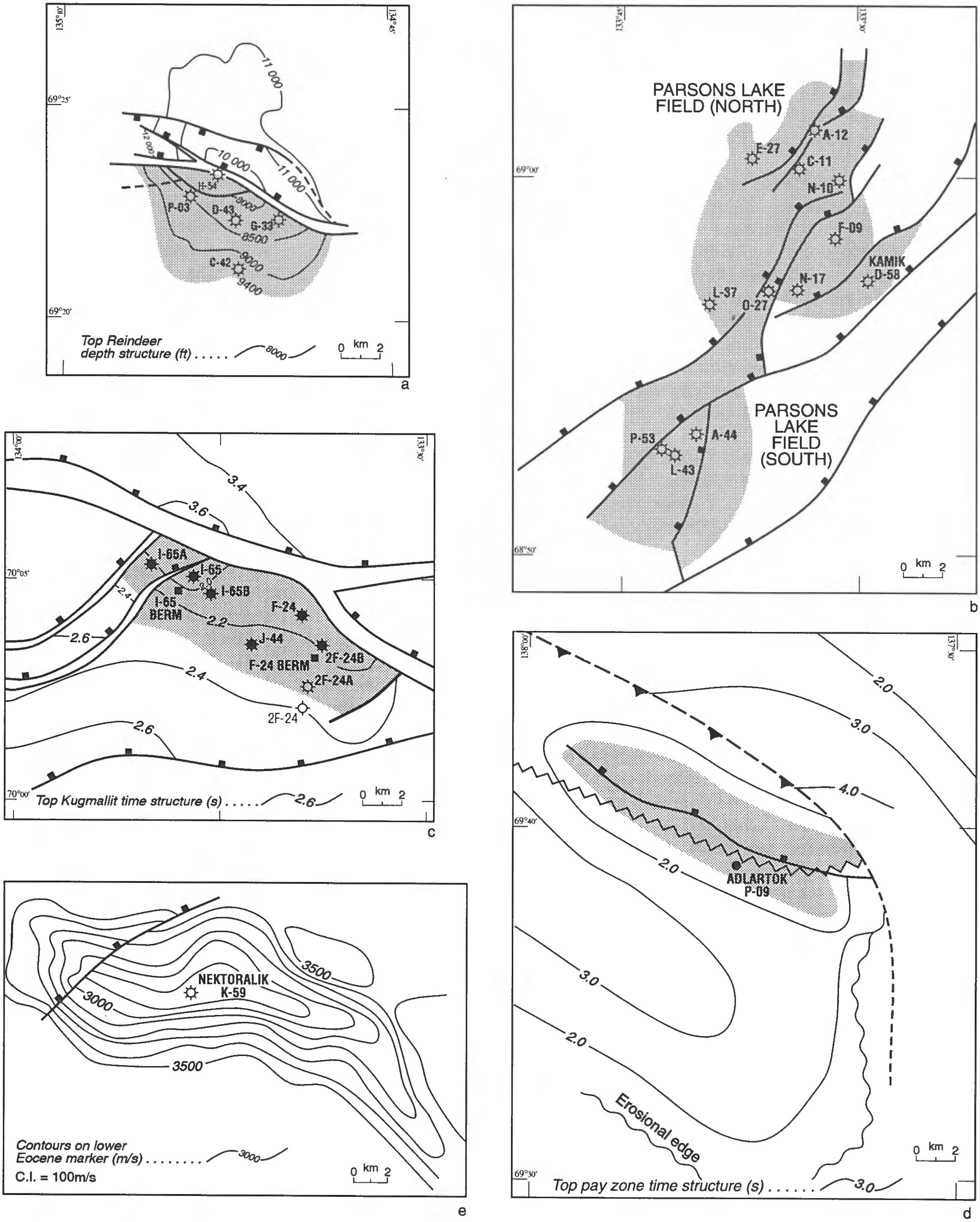

Figure 15.4. *Structural geometry of typical hydrocarbon reservoirs in the Mackenzie Delta–Beaufort Sea region. Figures 15.4a (Taglu), 15.4b (Parsons Lake), 15.4c (Amauligak) and 15.4d (Adlartok) are seismic maps after Campbell (1990). Figure 15.4e (Nektoralik) is a structure contour map after Jones et al. (1980).*

Beaufort–Mackenzie Basin appear to be synsedimentary with the deformation front migrating along as well as across the strike (Root, 1991). The whole may have been modified because of differential, seaward mass movement of the semiconsolidated to unconsolidated sedimentary succession comprising the Cenozoic delta systems of the ancestral and modern Mackenzie River (Norris, 1985, p. 803).

The eastern Beaufort–Mackenzie Basin embraces the bulk of the significant offshore hydrocarbon discoveries to date in southern Beaufort Sea (Fig. 15.1; Table 15.3). Shallow seismic reflection data reveal that the anticlinal reservoirs are irregularly shaped and their fold axes have no preferred direction (c.f. Ukalerk, Jones et al., 1980, fig. 11), suggesting that there has been no preferred direction of regional compression for the folding. However, families of extension faults truncating and offsetting the folds do have a preferred orientation; they trend east and northeast and have, for the most part, down-to-basin displacements. The fault-block geometry of these reservoirs, therefore, strongly suggests that the closures in the eastern Beaufort–Mackenzie Basin were due to differential compaction and diapirism upon which was superposed a domain of regional extension. One of the more prominent of these families of listric extension faults is the Tarsiut–Amauligak Fault System (Dixon et al., 1988, p. 43), extending curvilinearily from the Tarsiut Field eastward to Amauligak and Ukalerk.

According to Campbell (1990, p. 12), the Amauligak oil and gas field is a hydrocarbon discovery of major importance, ranking with Hibernia, offshore Newfoundland, and Point Arguello, offshore California, as one of the largest oil discoveries in North America in recent years. The structure is a fault block tilted gently south, elongate easterly, and cut by listric extension faults (Fig. 15.4c) on its north and south flanks. Reservoir sandstones according to Campbell (op. cit.) are confined to the lower Tertiary Kugmallit Sequence. Overlying shales of the Mackenzie Bay Sequence provide the seal, and underlying shales of the Richards, the source.

The structure of the western Beaufort–Mackenzie Basin is dominated by an arcuate array of buckle anticlines trending from northeast through east to southeast. Seismic reflection data indicate great lateral continuity for the closures, on the scale and style of the surface anticlines in Eagle Foldbelt. Like the latter, only a few folds on the shelf are asymmetric (Dietrich et al., 1989). However, many are cored with contraction faults verging northward (Lane and Dietrich, 1991) and some are cut by secondary extension faults.

Adlartok P–09, 50 km northeast of Herschel Island, is the first oil discovery in the western Beaufort–Mackenzie Basin. The anticlinal structure, verging slightly northeast, is thought to be typical of the western Beaufort–Mackenzie Basin. It is a local culmination along one of the high-amplitude anticlines and is contraction-faulted on its northeast flank (Fig. 15.4d). According to Campbell (1990, p. 13), the fault overlies a decollement zone in the Mesozoic section. The reservoir sandstones are thought to be the lower Eocene Aklak Sequence (lower Reindeer Formation). Potential source rocks include Tertiary shales of the lower Richards and lower Fish River sequences as well as oil-prone shales of the Upper Cretaceous Boundary Creek Sequence (Dixon et al., 1988).

Nektoralik K–59, on the outer edge of the continental shelf in the central Beaufort–Mackenzie Basin, was the first discovery of oil and gas among the deep-water wells. The structure is a southeast-trending anticline (Fig. 15.4e, after Jones et al., 1980) generated in response to migration of highly mobile shales beneath the mid-Tertiary, hydrocarbon-bearing Mackenzie Bay and Akpak sequences. Its curviplanar axial surface suggests the cumulative effects of the overprinting of successive, compressive deformations.

Oil and gas endowment, Beaufort–Mackenzie region

Assessment of the hydrocarbon potential of the Mackenzie Delta, Tuktoyaktuk Peninsula and southern Beaufort Sea region would indicate (Dixon et al., 1988; Campbell, 1990, p. 14) a total regional endowment of 7.1 billion barrels of oil (mean expectation), of which 1.4 billion has already been discovered. For gas, an endowment of 68 TCF (mean expectation) is anticipated, of which 12.3 TCF have been found to date.

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APPENDIX

Catalogue of Stratigraphic Sections+

System	Map area	Section no.	Synon.	Longitude	Latitude	Reference
T	107B	4	—	134°02′W	68°39′N	Price et al., 1980
T	107B	5*	—	134°12′W	68°45′N	Price et al., 1980
T	117A	18*	YA6	136°20′W	68°40′N	Young, 1975
T	117A	27	—	138°02′W	68°53′N	D.K. Norris, unpub. rep., 1971
T	117A	39*	YA4	136°16′W	68°33′N	Young, 1975
T	117A	44	—	137°59′W	68°51′N	D.K. Norris, unpub. rep., 1978
K–T	106E	16*	MJ5	135°15′W	65°48′N	Mountjoy, 1967
K–T	106E	17	MJ6	135°12′W	65°51′N	Mountjoy, 1967
K–T	106E	18	MJ7	135°07′W	65°53′N	Mountjoy, 1967
K	106E	7	—	134°09′W	65°51′N	F.G. Young, unpub. rep., 1970
K	106E	13	—	134°03′W	65°50′N	Mountjoy and Chamney, 1969
K	106F	1	—	133°40′W	65°55′N	Mountjoy and Chamney, 1969
K	106F	2	—	133°21′W	65°43′N	E.W. Mountjoy, unpub. rep., 1962
K	106F	3	—	133°10′W	65°52′N	E.W. Mountjoy, unpub. rep., 1962
K	106F	4	—	133°58′W	65°58′N	Mountjoy and Chamney, 1969
K	106L	3*	—	134°03′W	66°06′N	Mountjoy and Chamney, 1969
K	106L	4	—	134°35′W	66°14′N	E.W. Mountjoy, unpub. rep., 1962
K	106L	6	—	134°13′W	66°01′N	Mountjoy and Chamney, 1969
K	106L	7	—	135°06′W	66°32′N	E.W. Mountjoy, unpub. rep., 1962
K	106M	1*	JA118	135°42′W	67°05′N	Jeletzky, 1967
K	106M	2	—	135°40′W	67°52′N	T.P. Chamney, unpub. rep., 1962
K	106M	3	—	136°00′W	67°13′N	A. Jenik, unpub. rep., 1962
K	106M	4	—	135°29′W	67°06′N	D.K. Norris, unpub. rep., 1973
K	106M	5	CR6	135°28′W	67°54′N	Chamney, 1969
K	106M	8	—	135°06′W	67°20′N	D.K. Norris, unpub. rep., 1973
K	106M	15*	DFA 89-6	135°25′W	67°57′N	Dixon and Jeletzky, 1991
K	106M	16*	DFA 89–7	135°31′W	67°38′N	Dixon and Jeletzky, 1991
K	106N	1	—	133°46′W	67°26′N	G. Turnquist, unpub. rep., 1962
K	106N	2	—	133°33′W	67°26′N	G. Turnquist, unpub. rep., 1962
K	116F	2	—	140°49′W	65°08′N	F.G. Young, unpub. rep., 1970
K	116F	5b*	MJ1	140°14′W	65°03′N	Mountjoy, 1967
K	116F	12	—	140°44′W	65°23′N	E.W. Bamber, unpub. rep., 1962
K	116F	14	DFA 84–25	140°27′W	65°43′N	Norris, 1976
K	116J	2*	MJ2	139°01′W	66°29′N	Mountjoy, 1967
K	116J	14	—	138°05′W	66°40′N	G. Turnquist, unpub. rep., 1962
K	116O	1*	—	138°42′W	67°12′N	Jeletzky, 1975
K	116O	4	—	139°52′W	67°01′N	E.W. Mountjoy, unpub. rep., 1962
K	116P	12	—	136°13′W	67°27′N	T.P. Chamney, unpub. rep., 1962
K	116P	17*	DFA 82–8	137°18′W	67°58′N	Dixon and Jeletzky, 1991
K	107B	6	JA20	135°35′W	68°04′N	Jeletzky, 1958
K	107B	10	DFA 81–4	135°43′W	68°17′N	Dixon, 1991
K	107B	11	—	135°36′W	68°03′N	Mountjoy and Procter, 1969
K	107B	12	—	135°40′W	68°10′N	Mountjoy and Procter, 1969
K	107B	13	DFA 82–4	135°26′W	68°12′N	Dixon, 1991
K	107B	14*	DFA 81–1	135°35′W	68°12′N	Dixon and Jeletzky, 1991
K	107B	16	—	133°24′W	68°57′N	Dixon, 1982
K	107B	17*	—	133°32′W	68°59′N	Dixon, 1982
K	107B	18*	—	133°24′W	68°58′N	Dixon, 1982
K	107C	1*	—	131°51′W	69°44′N	Dixon, 1979
K	117A	4	—	137°28′W	68°25′N	Mountjoy and Procter, 1969
K	117A	9	—	137°49′W	68°38′N	Mountjoy and Procter, 1969
K	117A	10	—	137°52′W	68°10′N	E.W. Mountjoy, unpub. rep., 1962
K	117A	19	DFA 83–5	138°37′W	68°53′N	Dixon, 1991
K	117A	23	—	138°15′W	68°51′N	E.W. Mountjoy, unpub. rep., 1962
K	117A	33*	YA1	136°24′W	68°31′N	Young, 1975
K	117A	38*	YA2	136°23′W	68°31′N	Young, 1975
K	117D	2	—	138°32′W	69°02′N	Norris in Bamber et al., 1982
J–K	116J	13	DFA 85–21	139°54′W	66°51′N	Dixon, 1991
J–K	116K	1	—	140°12′W	66°10′N	D.K. Norris, unpub. rep., 1970
J–K	116P	2	—	137°16′W	67°57′N	Mountjoy and Procter, 1969
J–K	117A	2	—	136°56′W	68°09′N	Mountjoy and Procter, 1969
J–K	117A	5	PU 19–76	136°31′W	68°18′N	Poulton et al., 1982

APPENDIX (cont'd.)

System	Map area	Section no.	Synon.	Longitude	Latitude	Reference
J–K	117A	12	—	139°05′W	68°35′N	E.W. Mountjoy, unpub. rep., 1962
J–K	117A	16	CR9	138°50′W	68°47′N	Chamney in Mountjoy and Procter, 1969
J–K	117A	17	—	138°23′W	68°41′N	E.W. Mountjoy, unpub. rep., 1962
J–K	117A	22	—	138°20′W	68°44′N	B.S. Norford, unpub. rep., 1962
J–K	117A	24	—	138°05′W	68°18′N	E.W. Mountjoy, unpub. rep., 1962
J–K	117A	34	DFA 87–17	138°02′W	68°29′N	Dixon, 1991
J	106M	9	PU 22–76	135°55′W	67°54′N	Poulton et al., 1982
J	116H	16	—	136°43′W	65°50′N	E.W. Bamber, unpub. rep., 1962
J	116P	5	—	136°35′W	67°54′N	L.D. Dyke, unpub. rep., 1970
J	116P	6	PU 12, 14–75	136°25′W	67°58′N	Poulton et al., 1982
J	116P	8	PU 11–76	137°19′W	67°47′N	Poulton et al., 1982
J	116P	14	—	137°57′W	67°24′N	L.D. Dyke, unpub. rep., 1970
J	116P	17	PU 21–76	136°41′W	67°49′N	Poulton et al., 1982
J	116P	18	PU 32–76	136°49′W	67°57′N	Poulton et al., 1982
J	116P	19	PU 5–78	137°08′W	67°44′N	Poulton et al., 1982
J	116P	20	PU 6–78	137°07′W	67°48′N	Poulton et al., 1982
J	116P	21*	—	137°47′W	67°24′N	Jeletzky, 1977
J	107B	7*	PU 7–75	135°28′W	68°04′N	Poulton et al., 1982
J	107B	8	PU 12–76	135°30′W	68°02′N	Poulton et al., 1982
J	107B	9	PU 2–78	135°40′W	68°12′N	Poulton et al., 1982
J	107B	15*	JA22	135°25′W	68°02′N	Jeletzky, 1967
J	117A	1	—	136°05′W	68°07′N	Mountjoy and Procter, 1969
J	117A	40	PU 10–76	136°12′W	68°06′N	Poulton et al., 1982
J	117A	41	PU 20–76	136°11′W	68°25′N	Poulton et al., 1982
J	117A	42	PU 18–76	136°57′W	68°11′N	Poulton et al., 1982
J	117A	43	PU 27–76	136°34′W	68°05′N	Poulton et al., 1982
Tr	116I	8	MJ7	136°08′W	66°59′N	Mountjoy, 1967
Tr	117A	20	MJ4	139°03′W	68°41′N	Mountjoy, 1967
Tr	117A	21	MJ5	139°11′W	68°41′N	Mountjoy, 1967
Tr	117A	25	MJ6	138°28′W	68°36′N	Mountjoy, 1967
Tr	117D	1	MJ2	139°49′W	69°20′N	Mountjoy, 1967
Pr–K	116F	11	—	140°42′W	65°34′N	D.K. Norris, unpub. rep., 1970
Pr–J	116P	1	—	136°10′W	67°59′N	Poulton et al., 1982
Pr–J	117A	30	—	136°35′W	68°04′N	Dyke in Bamber et al., 1982
Pr–Tr	117A	29	—	139°53′W	68°42′N	Norris in Bamber et al., 1982
Pr–Tr	117B	1	MJ1	141°05′W	68°55′N	Mountjoy, 1967
Pr	106M	7b	—	135°48′W	67°52′N	Bamber, 1972
Pr	116C	1	—	140°52′W	65°00′N	Bamber, 1972
Pr	116C	2*	—	140°54′W	64°59′N	Bamber and Waterhouse, 1971
Pr	116F	1	—	140°32′W	65°08′N	Bamber, 1972
Pr	116F	13	—	140°44′W	65°24′N	Bamber, 1972
Pr	116F	16	—	140°43′W	65°17′N	Bamber, 1972
Pr	116F	17	—	140°24′W	65°17′N	Bamber, 1972
Pr	116F	18	—	140°48′W	65°21′N	Bamber, 1972
Pr	116H	17	—	136°52′W	65°50′N	Bamber, 1972
Pr	116P	9	—	136°02′W	67°47′N	Bamber, 1972
Pr	116P	10	—	136°32′W	67°31′N	Bamber, 1972
Pr	116P	11	—	136°19′W	67°41′N	Bamber, 1972
Pr	116P	13	—	137°46′W	67°27′N	W.W. Nassichuk, unpub. rep., 1973
Pn–Pr	116G	5	—	138°33′W	65°38′N	Bamber, 1972
Pn–Pr	116G	11	—	139°37′W	65°41′N	Bamber, 1972
Pn–Pr	116H	1A	—	136°08′W	65°53′N	Bamber and Waterhouse, 1971
Pn–Pr	116J	7	—	139°38′W	66°59′N	Bamber and Waterhouse, 1971
Pn	116F	9*	—	140°40′W	65°25′N	Bamber and Waterhouse, 1971
M–Tr	117A	7	—	138°24′W	68°34′N	L.D. Dyke, unpub. rep., 1973
M–Tr	117A	13	—	138°57′W	68°51′N	Bamber, 1972
M–Tr	117A	37	—	139°18′W	68°50′N	Norris in Bamber et al., 1982
M–Pr	117A	3	ZB12	139°58′W	68°50′N	Mamet and Mason, 1970
M–Pr	117A	6	ZA6	139°14′W	68°44′N	Mamet and Mason, 1970
M–Pn	116G	9	—	138°55′W	65°48′N	Bamber, 1972
M–Pn	116J	4a	—	138°50′W	66°01′N	Bamber and Waterhouse, 1971
M–Pn	117A	11	—	139°06′W	68°49′N	U. Upitis, unpub. rep., 1962

APPENDIX (cont'd.)

System	Map area	Section no.	Synon.	Longitude	Latitude	Reference
M–Pn	117A	15	—	138°23′W	68°27′N	Bamber and Waterhouse, 1971
M–Pn	117B	2	—	140°59′W	68°57′N	A.W. Norris, unpub. rep., 1962
M–Pn	117B	20	—	140°52′W	68°54′N	Bamber and Waterhouse, 1971
M–Pn	117C	2	—	140°35′W	69°23′N	Bamber, 1972
M	106F	20	—	133°47′W	65°32′N	H. Walton, unpub. rep., 1962
M	116F	3	—	140°21′W	65°29′N	D.K. Norris, unpub. rep., 1970
M	116H	1b*	—	136°06′W	65°53′N	Bamber and Waterhouse, 1971
M	116H	25	—	136°16′W	65°52′N	Bamber and Waterhouse, 1971
M	116I	5	—	136°26′W	66°10′N	E.W. Bamber, unpub. rep., 1962
M	116I	6	—	136°47′W	66°09′N	Bamber, 1972
M	116I	7	—	136°38′W	66°11′N	Bamber, 1972
M	116I	8*	—	137°31′W	66°08′N	Martin, 1972
M	116J	4	—	138°50′W	66°09′N	Bamber, 1972
M	117B	3	—	140°50′W	68°42′N	Bamber, 1972
M	117C	3	—	141°05′W	69°26′N	Bamber and Waterhouse, 1971
D–Pr	116P	3	NB34	136°25′W	67°28′N	A.W. Norris, 1967
D–Pr	116P	4	NB33	136°20′W	67°40′N	A.W. Norris, 1967
D?–Pr	117A	8	—	136°23′W	68°16′N	Bamber and Waterhouse, 1971
D	106E	1	NB11	135°43′W	65°15′N	A.W. Norris, 1968
D	106E	14	NB7	134°11′W	65°23′N	A.W. Norris, 1967
D	106F	5	NB4	132°17′W	65°07′N	A.W. Norris, 1967
D	106F	6	NB3	132°01′W	65°27′N	A.W. Norris, 1968
D	106F	11*	NB6	133°37′W	65°27′N	A.W. Norris, 1968
D	106G	1	NB1	130°46′W	65°21′N	A.W. Norris, 1968
D	106G	2	NB2	131°21′W	65°24′N	A.W. Norris, 1967
D	106L	5	NB35	135°26′W	66°26′N	A.W. Norris, 1968
D	116F	8	—	140°18′W	65°27′N	A.W. Norris, unpub. rep., 1970
D	116F	15	NB23a	140°49′W	65°23′N	A.W. Norris, 1968
D	116G	2	—	139°24′W	65°26′N	A.W. Norris, unpub. rep., 1970
D	116G	3	—	138°10′W	65°14′N	A.W. Norris, unpub. rep., 1970
D	116G	4	NB23	139°09′W	65°28′N	A.W. Norris, 1967
D	116G	6	—	139°27′W	65°32′N	A.W. Norris, unpub. rep., 1970
D	116G	7	—	138°13′W	65°17′N	A.W. Norris, unpub. rep., 1970
D	116G	12	—	138°13′W	65°28′N	A.W. Norris, 1985
D	116G	15	—	138°33′W	65°04′N	A.W. Norris, unpub. rep., 1970
D	116H	2*	NB14	136°45′W	65°38′N	A.W. Norris, 1968
D	116H	9	NB17	137°06′W	65°25′N	A.W. Norris, 1967
D	116H	18	—	137°57′W	65°30′N	A.W. Norris, unpub. rep., 1970
D	116J	3	MJ27	139°25′W	66°37′N	A.W. Norris, 1967
D	116J	5*	NB24	139°36′W	66°03′N	A.W. Norris, 1968
D	116J	9	NB28	139°15′W	66°43′N	A.W. Norris, 1967
D	116J	12	NB25	139°10′W	66°10′N	A.W. Norris, 1967
D	107B	1	NB31	133°28′W	68°10′N	A.W. Norris, 1967
D	107B	2	NB32	133°24′W	68°16′N	A.W. Norris, 1967
D	117A	26	—	138°13′W	68°01′N	A.W. Norris, unpub. rep., 1970
S–D	116G	10	NB21	138°44′W	65°33′N	A.W. Norris, 1967
S–D	116H	4	—	136°55′W	65°35′N	B.S. Norford, unpub. rep., 1962
S–D	116H	11	NB16	137°00′W	65°28′N	A.W. Norris, 1967
S–D	116H	13	NB19	137°26′W	65°42′N	A.W. Norris, 1967
S–D	116J	10	NB26	139°18′W	66°13′N	A.W. Norris, 1968
S–D	116O	7	NE24	138°10′W	67°34′N	Norford, 1964
S–D	116P	15	NB47	136°33′W	67°58′N	A.W. Norris, 1985
O–D	106E	12	MQ16	135°05′W	65°03′N	Macqueen, 1974
O–D	106E	21	NE7	135°39′W	65°17′N	Norford, 1964
O–D	116G	8	NB20	138°15′W	65°23′N	Norford, 1964
O–D	116H	5	NE8	136°13′W	65°24′N	Norford, 1964
O–D	116H	8	NE10	137°11′W	65°41′N	Norford, 1964
O–D	116H	14	—	136°37′W	65°07′N	A. Jenik, unpub. rep., 1962
O–D	116I	1	NE18	136°05′W	66°10′N	Norford, 1964
C–D	106F	13	NE2	133°00′W	65°29′N	Norford, 1964
C–D	106L	2*	NE21	135°47′W	65°43′N	Norford, 1964
C–D	116H	12	—	136°14′W	65°12′N	U. Upitis, unpub. rep., 1962
C–D	116I	2	NE22	136°15′W	66°48′N	Norford, 1964

APPENDIX (cont'd.)

System	Map area	Section no.	Synon.	Longitude	Latitude	Reference
O–S	106E	15	NE6	135°09′W	65°03′N	Norford, 1964
O–S	116H	6	—	137°18′W	65°26′N	B.S. Norford, unpub. rep., 1962
O–S	116H	15	NE11	137°23′W	65°24′N	Norford, 1964
O–S	117A	14	—	138°07′W	68°24′N	B. Norford, unpub. rep., 1962
O–S	117A	28	—	138°19′W	68°33′N	A.W. Norris, unpub. rep., 1970
O–S	117A	31	—	138°14′W	68°32′N	A.W. Norris, unpub. rep., 1970
O–S	117A	32	—	138°09′W	68°25′N	A.W. Norris, unpub. rep., 1970
O–S	117A	35	—	138°10′W	68°28′N	Dyke in Bamber et al., 1982
O–S	117A	36	—	138°14′W	68°27′N	Dyke in Bamber et al., 1982
C–S	116C	3	NE14	139°35′W	64°55′N	Norford, 1964
C–S	116G	1	—	139°22′W	65°38′N	B. Norford, unpub. rep., 1962
S	106E	5	NE5	135°12′W	65°14′N	Norford, 1964
S	106E	8	NE3	134°14′W	65°51′N	Norford, 1964
S	106F	14	MQ10	133°56′W	65°24′N	Macqueen, 1974
S	116K	4	NE17	140°46′W	66°58′N	Norford, 1964
O	116H	10	NE9	136°41′W	65°13′N	Norford, 1964
C–Pr	116P	7*	NE23	136°35′W	67°55′N	Norford, 1964
C–D	116K	3	—	140°50′W	66°55′N	R.M. Procter, unpub. rep., 1962
C–O	116F	4	NE15	140°18′W	65°24′N	Norford, 1964
C–O	116F	6	—	140°55′W	65°17′N	B.S. Norford, unpub. rep., 1962
C–O	116F	10	MJ238	140°14′W	65°24′N	E.W. Mountjoy, unpub. rep., 1962
C	106E	3*	FN8	135°32′W	65°45′N	Fritz, 1974
C	106E	6	FN6	135°18′W	65°21′N	Fritz, 1974
C	106E	19*	FN7	134°43′W	65°05′N	Fritz, 1974
C	106E	20	—	134°46′W	65°02′N	U. Upitis, unpub. rep., 1962
C	106E	22	—	134°38′W	65°20′N	A.S. Hedinger, unpub. rep., 1973
C	106E	4	—	135°11′W	65°17′N	R.M. Procter, unpub. rep., 1962
C	106L	1	FN5	135°55′W	66°10′N	Fritz, 1974
C	106L	8	—	135°37′W	66°27′N	B.S. Norford, unpub. rep., 1962
C	106L	9	NE19	135°32′W	66°25′N	Norford, 1964
C	106L	10	FN4	135°50′W	66°38′N	Fritz, 1974
C	106M	7a	FN3	135°48′W	67°52′N	Fritz, 1974
C	116P	16	FN1	138°45′W	67°59′N	Fritz, 1974
?Hd	106E	2	—	134°20′W	65°22′N	L.D. Dyke, unpub. rep., 1973
?Hd	106E	10	—	134°22′W	65°28′N	L.D. Dyke, unpub. rep., 1973
Hd	106F	8	—	133°11′W	65°14′N	L.D. Dyke, unpub. rep., 1973
?Hd	116G	13	—	139°44′W	65°46′N	D.K. Norris, unpub. rep., 1970
?Hd	117C	1	—	139°15′W	69°04′N	Dyke in Bamber et al., 1982
?Hd	117C	4	—	140°01′W	69°03′N	Procter in Bamber et al., 1982
He–C	116K	2	—	140°30′W	66°39′N	R.M. Procter, unpub. rep., 1962
He–Hd	106F	10	—	133°17′W	65°15′N	R.M. Procter, unpub. rep., 1962
He	106E	9	—	134°58′W	65°12′N	A.S. Hedinger, unpub. rep., 1973
He	106E	11	—	134°02′W	65°18′N	A.S. Hedinger, unpub. rep., 1973
He	106F	7	—	132°41′W	65°28′N	R.M. Procter, unpub. rep., 1962
He	106F	9	—	133°35′W	65°20′N	R.M. Procter, unpub. rep., 1962
He	106F	12	—	133°56′W	65°18′N	A.S. Hedinger, unpub. rep., 1973
He	106F	15	—	133°35′W	65°19′N	L.D. Dyke, unpub. rep., 1973
?He	106M	6	—	135°55′W	67°39′N	D.K. Norris, unpub. rep., 1973
He	116F	7	—	140°16′W	65°22′N	L.D. Dyke, unpub. rep., 1973
He	116G	14	—	138°05′W	65°01′N	L.D. Dyke, unpub. rep., 1973
?He	116N	1	—	140°50′W	67°25′N	R.M. Procter, unpub. rep., 1962
?He	116N	2	—	140°33′W	67°28′N	R.M. Procter, unpub. rep., 1962
?He	116N	3	—	140°58′W	67°25′N	R.M. Procter, unpub. rep., 1962
?He	116N	4	—	140°55′W	67°25′N	R.M. Procter, unpub. rep., 1962
He	107B	3	—	133°32′W	68°18′N	R.M. Procter, unpub. rep., 1962

* Type section

\+ This appendix contains all type sections in both surface and subsurface rocks in the project area in addition to other known worthwhile surface sections, beginning with measurements taken in 1962. Sections are tabulated by System, and identified by NTS map area followed by a section number which locates them in an area (e.g., 116F9). In some cases, authors have retained synonymous field or publication identification numbers; these have been included for clarity and ease of tracking down the sections. Where applicable, scientists with the Geological Survey of Canada are identified by their unique field letters (e.g., NE is B.S. Norford).

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