Thomas Frisch

GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

MEMOIR 373

TUCHODI LAKES MAP-AREA, BRITISH COLUMBIA

G. C. Taylor and D. F. Stott

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TUCHODI LAKES MAP-AREA,

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Thrust fault rooting in décollement at base of Nonda Formation, headwaters of Wokkpash Creek.

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PREFACE

An objective of the studies carried out by the Geological Survey is to estimate the potential abundance and probable distribution of the mineral and fuel resources available to Canada. Such estimates depend on the availability of information concerning the geological framework, and in this report the age, structure, sequence, relationships, thickness and origin of a succession of rocks in the northern Rocky Mountains are described.

The data were collected during Operation Liard, a helicopter-supported reconnaissance geological study of the Rocky Mountains and Rocky Mountain Foothills of northeastern British Columbia. Because of its location, Tuchodi Lakes map-area is of prime importance in that it provides a key to the understanding of both stratigraphy and structure of much of the northern Rocky Mountains. In addition, the data presented are sufficiently detailed so as to permit evaluation of the petroleum potential of the region.

Y. O. FORTIER,
Director, Geological Survey of Canada

OTTAWA, August 1972

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TUCHODI LAKES MAP-AREA, BRITISH COLUMBIA

Abstract

Tuchodi Lakes map-area in northeastern British Columbia lies between 58° and 59°N latitude and 124° and 126°W longitude. The accompanying map shows the bedrock geology of the area on a scale of 1:125,000.

The map-area includes parts of three main physiographic subdivisions; the Rocky Mountains, Rocky Mountain Foothills, and the Interior Plains. Alpine glaciation has extensively sculptured the mountain areas and higher foothills, whereas continental glaciation had little effect on the topography of the Interior Plains and eastern Foothills.

The sequence of strata in the map-area includes seven Helikian formations and one of Hadrynian age unconformably overlain by Cambrian clastic and carbonate strata which, in turn, are unconformably overlain by Ordovician carbonate beds. All these together comprise a pseudo-basement for four, later, naturally associated stratigraphic assemblages separated by detachment surfaces, as follows: (1) a Lower Silurian to Middle Devonian carbonate sequence; (2) a predominantly clastic Upper Devonian through Permian sequence; (3) a predominantly clastic Triassic sequence; and (4) a clastic Cretaceous sequence.

All successions listed have been deformed by orogenic processes but each assemblage has responded differently to these deformative forces. Thus, five structural "packets" are recognized, all separated by detachments and each characterized by a different structural style.

Significant mineralization, particularly copper, occurs within the map-area. The area may contain petroleum accumulations, since potential source, reservoir, and trap rocks, as well as favourable structures are present.

Résumé

La région des lacs Tuchodi, dans le nord-est de la Colombie-Britannique, est située entre les 58ᵉ et 59ᵉ degrés de latitude nord et les 124ᵉ et 126ᵉ degrés de longitude ouest. La carte ci-annexée illustre la géologie du socle à l'échelle du 1:125,000.

La région étudiée comprend certaines parties de trois sous-divisions physiographiques importantes: les Rocheuses, les Foothills et les Plaines Intérieures. Les glaciations alpines ont profondément altéré les montagnes et les zones les plus élevées des Foothills, alors que la glaciation continentale a très peu touché la topographie des Plaines Intérieures et celle de l'est des Foothills.

La suite des couches de la région comprend sept formations hélikiennes et une seule d'âge hadrynien, sur laquelle repose en discordance des couches d'argiles et de roches carbonatées du Cambrien sur lesquelles reposent, encore en discordance, des couches de roches carbonatées de l'Ordovicien. Le tout

forme une sorte de sous-sol à quatre assemblages évidemment plus récents séparés par des surfaces de décollement: (1) séquence carbonatée du Silurien ancien au Dévonien moyen (2) séquence clastique, Dévonien récent au Permien (3) séquence clastique du Trias et (4) séquence clastique du Crétacé.

Toutes les séquences ont été déformées par les processus orogéniques, mais chaque assemblage a réagi différemment. On a reconnu cinq «groupes» structuraux, tous séparés par des décollements et caractérisés par un style différent.

La région offre certaines minéralisations intéressantes, notamment du cuivre. Il se peut également qu'on y trouve du pétrole, puisque la région offre des roches réservoirs, des pièges et d'autres structures propices.

INTRODUCTION

Tuchodi Lakes map-area (94K), in northeastern British Columbia, is bounded by latitudes 58° and 59°N and longitudes 124° and 126°W. It forms a part of the larger region investigated by the personnel of Operation Liard (*see* Taylor, 1965, 1966) during the summers of 1964 and 1965. The map-area is bordered on the north by Toad River (94N) map-area, to the east by Fort Nelson (94J) map-area (Taylor and Stott, 1968b), on the south by Ware (94F) map-area, and to the west by Kechika (94L) map-area (Gabrielse, 1962a, b). The Alaska Highway cuts through the northern part of the map-area providing easy access to much of the geology.

Field Work and Acknowledgments

The Geological Survey party on Operation Liard comprised E. W. Bamber, R. T. Bell, D. F. Stott, and G. C. Taylor. Taylor was the officer in charge of the operation and was responsible for the mapping and for much of the pre-Cretaceous stratigraphy. D. F. Stott was responsible for the Cretaceous stratigraphy, E. W. Bamber for the Carboniferous and Permian stratigraphy, and R. T. Bell for the Proterozoic stratigraphy. Other officers of the Survey who availed themselves of the facilities of the operation for specific projects include W. S. MacKenzie, B. S. Norford, R. M. Procter, R. Thorsteinsson, and E. T. Tozer. Discussions with these geologists have been of great value during all phases of the structural and stratigraphic investigations.

The staff was ably assisted in the field during 1964 by D. Hetherington, M. E. Wooding, R. Armstrong, and D. MacDougal; and during 1965, by W. R. Craig, L. G. Grainger, and B. J. Reive. Cooks were S. W. McWhinnie and I. Severson. Helicopters were supplied by Bullock Wings and Rotors and manned by J. Davies, H. Tetz, M. Brown, and P. Ettinger. To all these men, the writers and other officers of the party extend their appreciation.

All fossils were identified by staff of the Paleontology section of the Geological Survey of Canada unless otherwise noted.

Previous Work

The first geological work bearing directly on this area was published by Williams (1923) after a trip from Fort St. John north to Sikanni Chief River and down Sikanni Chief and Fort Nelson Rivers to Liard River. Reconnaissance studies within the Tuchodi Lakes map-area, which were initiated during the Second World War to determine the economic potential of the region, were facilitated by the opening of

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the Alaska Highway. Williams (1944) studied the geology along the highway west from Fort Nelson to the map-area and beyond. Hage (1944) studied the geology adjacent to the highway as far north as Fort Nelson. Kindle (1944) descended the Fort Nelson River and then continued westward up the Liard River. McLearn (1945) became interested in the fossils collected by Kindle and published one of many reports dealing with the Triassic and Cretaceous faunas of northeastern British Columbia. Laudon and Chronic (1947, 1949) were the first to study the Paleozoic rocks in detail. McLearn and Kindle (1950) published a summary of the known geology of northeastern British Columbia.

Two 1 inch=1 mile map-areas have been published of areas included within the Tuchodi Lakes map-area. Pelletier (1959) and Taylor (1963) reported on the Tetsa River and MacDonald Creek map-areas respectively. Pelletier (1960, 1961, 1962) and Stott (1967, 1968) have published stratigraphic studies of the Triassic and Cretaceous rocks respectively. Bamber *et al.* (1968) have reported on the late Paleozic strata, Norford *et al.* (1966) on the Silurian strata, Bell (1968) on the Proterozoic strata, and Taylor and MacKenzie (1970) on the Devonian strata. Reports and maps of adjacent areas include: Kechika, and Rabbit River map-areas (Gabrielse, 1962a, b); Trutch map-area (Pelletier and Stott, 1963); Maxhamish Lake, and Fort Nelson map-areas, (Taylor and Stott, 1968a, b); and Halfway River map-area (Irish, 1970).

In addition to Geological Survey of Canada reports, Cosburn and Callum (1962) and Hughes (1963) have reported on the Devonian carbonates; Kidd (1962, 1963) and Pelzer (1966) have reported on the Devonian shales; and Fitzgerald and Braun (1965), and Fitzgerald (1968) have reported on the structure of the foothills.

Physical Features

The map-area lies on both sides of the Alaska Highway 64 miles west of Fort Nelson. The highway runs east–west through the northern one-third of the area providing all-weather access to much of the region.

Three major physiographic subdivisions are recognized: (1) the Rocky Mountains, which are underlain by middle Paleozoic and older carbonates, characterized by high peaks with average summit elevations of 8,000 feet, deeply dissected, glaciated and largely devoid of vegetation above the treeline at about 4,500 feet; (2) the Foothills, consisting of low, linear, rounded wooded hills in the east, and higher, generally elongate isolated hills in the west, all underlain by clastic rocks of late Paleozoic and Mesozoic ages and; (3) the Interior Plains characterized by high, tree-topped mesas of Cretaceous sandstone.

Glaciation has had little effect on the topography of the Plains and Foothills. In contrast, many cirques have been developed on the mountains and higher foothills, and extensive icefields and small glaciers still exist on the higher mountains. Most of the valleys in the mountain region exhibit a U-shaped cross-section and many are occupied now by braided streams. The area is only lightly veneered with glacial debris except in the major stream valleys. Locally, as along Wokkpash Creek and near Summit Lake, numerous erosion pillars have been produced by consolidation of thick deposits of till. Boulders of Cambrian conglomerate, occurring east of the Stone Range divide, indicate that the alpine ice overflowed the crest of the range.

STRATIGRAPHY

With the exception of minor basic intrusives, all bedrock exposed and studied within the map-area is of sedimentary origin. The age of the strata range from Helikian[1] to Upper Cretaceous and the aggregate thickness is in excess of 60,000 feet. Strata representative of all systems except the Jurassic are known, and it is possible that erosional remnants of Jurassic formations occurring to the south are preserved locally. One prominent paleogeographic feature, the MacDonald Platform (Gabrielse, 1967), has affected the sedimentation pattern of almost all the Phanerozoic deposits. Centred near what is called the Tuchodi Anticline, the Platform behaved as a relatively positive element throughout the depositional history of the region. Most formations are much thinner on the Platform than in adjacent regions, and many that were once deposited were later eroded.

Certain gross characteristics of lithology enable the stratigraphic column to be divided into five natural "packets" of rock that have controlled fundamentally the structural development of the area. The five packets, all separated by detachment surfaces, and each showing the results of a different response to deformative forces, are:

(1) Helikian through Ordovician strata, within which complex early tectonism destroyed the structural inhomogeneity of original bedding, thereby producing what is referred to as a "pseudo-basement" during Laramide deformation;

(2) Silurian through Middle Devonian carbonates, dominantly dolomite, within which prominent bedding planes and brittle response resulted in the development of low-angle thrust faults;

(3) Upper Devonian through Permian, composed of thin competent beds of fine clastic sediments enveloped in incompetent shales and occurring now in disharmonic folds of small amplitude and wavelength;

(4) Triassic clastic strata with thicker competent sandstone units that now occur as large *en échelon*-linked cylindrical folds;

(5) Cretaceous fine clastic rocks with very thick competent sandstone members that formed very large, open upright folds.

The Helikian sediments of the Chischa, Tetsa, George, Henry Creek, and eastern representatives of the Tuchodi Formation were deposited under shallow water shelf conditions (Pl. I; Tuchodi-point bars). Only rocks of the Tuchodi Formation are preserved over a sufficiently wide area to record significant facies change. Western elements of the formation record deposition in deeper waters, and the younger flysch-like rocks of the Aida and Gataga Formations are both relatively deep water, dominantly clastic sediments (Pl. II; Aida flame structures).

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[1] For usage of the terms Helikian and Hadrynian *see* Stockwell, 1964.

Table of Formations

EON	ERA	AGE	ROCK UNIT		THICKNESS (IN FEET)
PHANEROZOIC	MESOZOIC	CRETACEOUS, Late	KOTANEELEE FORMATION		?
			Disconformity		
			DUNVEGAN FORMATION		550+
		CRETACEOUS, Early	FORT ST. JOHN GROUP	SULLY FORMATION	300
				SIKANNI FORMATION	900
				BUCKINGHORSE FORMATION	4,000
		Angular unconformity			
		TRIASSIC	PARDONET FORMATION		0-600
			BALDONNEL FORMATION		
			LUDINGTON FORMATION		0-1,000
			LIARD FORMATION		0-600
			TOAD FORMATION		1,200-2,500
			GRAYLING FORMATION		1,000-1,500
		Angular unconformity			
	PALEOZOIC	PERMIAN	FANTASQUE FORMATION		0-120
			Disconformity		
			KINDLE FORMATION		0-600
		PENNSYLVANIAN	Disconformity		
		MISSISSIPPIAN	STODDART FORMATION		0-535
			PROPHET FORMATION		0-300
		DEVONIAN, Late	BESA RIVER FORMATION		1,200
		DEVONIAN, Middle	DUNEDIN FORMATION		800
			Local disconformity		
			STONE FORMATION		1,035-1,935
		DEVONIAN, Early	Disconformity		
			WOKKPASH FORMATION		150-350
			MUNCHO - McCONNELL FORMATION		350-800
			Disconformity		
		SILURIAN	NONDA FORMATION		600-1,200
		Angular unconformity			
		ORDOVICIAN	KECHIKA GROUP		2,000-6,000
		Angular unconformity			
		CAMBRIAN	ATAN GROUP		2,000-6,000
			Disconformity		
PROTEROZOIC	HADRYNIAN		Unnamed succession		4,000+
	Angular unconformity				
	HELIKIAN		Gabbroic Dykes		25-250
			GATAGA FORMATION		4,500+
			AIDA FORMATION		3,470-7,100
			TUCHODI FORMATION		5,000+
			HENRY CREEK FORMATION		700-1,500
			GEORGE FORMATION		1,170-1,750
			TETSA FORMATION		1,030
			Disconformity		
			CHISCHA FORMATION		3,100+

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PLATE I. Bar sandstones in the Tuchodi Formation.

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PLATE II. Flame structures in Aida Formation argillites.

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PLATE III. "Patch reefs" or archaeocyathid mounds at carbonate front, Early Cambrian Atan Group.

Hadrynian strata occurring only west of the Gundahoo Fault can be mapped southward into the Misinchinka schists. These schists, in turn, can be traced into strata of the type Miette Group which is considered to be correlative with the Windermere Group. Apparently only upper Miette equivalents are present in the Tuchodi map-area although quartz(rutilated)-pebble conglomerates of middle Miette type are present in the adjoining Kechika and Rabbit River map-areas.

The Early Cambrian is represented by a sequence of tectonic fanglomerates that pass westward into normal marine sediments of the Atan Group. The facies front (Pl. III) of the prominent Atan limestone is particularly sharp in the Tuchodi Lakes map-area in contrast to the more transitional boundary to the south in the Ware map-area. No known Middle Cambrian sediments are preserved in the Tuchodi Lakes map-area, the sedimentary record being resumed in strata of earliest Ordovician age. Rapid submergence is indicated by the lowest sediments of the Kechika Group followed by shoaling conditions which resulted in deposition of a thick succession of open marine carbonates. Facies change within the Kechika from the platform carbonates on the east to graptolitic shales in the west is marked by a narrow zone of turbidites that presumably sloughed off the slope separating the two main levels of deposition within the basin. The Ordovician rests with angular unconformity on all other units (*see* Pl. IV). Pre-Nonda (Silurian) orogeny resulted in strong folding of the column to produce a substrata or pseudo-basement on which later carbonates were deposited unconformably.

The second structural-stratigraphic packet is composed of a blanket-like succession of Silurian to Middle Devonian carbonate strata. All were deposited on a relatively open water platform facing a shale basin to the west. The major local facies variants are attributable to and define the MacDonald Platform, and only minor facies effects can be attributed to the Peace River Arch. Sediments typical of progressively shallower water were deposited in a regressive sequence culminating in the semi-evaporitic Stone Formation. A return to deeper water conditions is recorded by strata of the overlying Dunedin Formation.

The third structural-stratigraphic packet consists of Upper Devonian through Permian strata. A sediment-starved basin was developed and deposition of black shale superseded carbonate deposition over much of the area. Locally, on the eastern margin of the map-area, the formation of carbonate beds persisted during Mississippian (Prophet) time; it was followed by an influx of clastic sediments from the north during Mattson time. The record of Pennsylvanian deposition is extremely meagre but, prior to Early Permian time, strong deformation in the north resulted in removal of much of the Mattson–Stoddart sedimentary record. The resulting unconformity is prominent in the eastern part of Tuchodi Lakes map-area but obscure in the western part. During the Early Permian, fine clastic sediments, followed by the thin, siliceous or cherty Fantasque Formation were deposited over much of the area. The record of Late Permian deposition is not preserved.

The fourth packet consists of dominantly clastic rocks of Triassic age with only the earliest and latest stages of the Triassic appearing to be absent. The Toad–Grayling and Liard Formations represent a regressive succession apparently derived from the east. Westward migration of the site of Liard sandstone deposition with time is indicated by the diachronous relationships of the associated faunas. The Ludington Formation was deposited during a transgressive phase, and the carbonates of the Pardonet Formation cap the succession as successor deposits in a previously clastic environment.

The fifth structural-stratigraphic packet is composed of dominantly marine deposits of Cretaceous age unconformably overlying Triassic strata. In contrast with earlier sediments, those of Cretaceous formations were derived from the west.

Proterozoic

Rocks of Proterozoic age in the Tuchodi Lakes map-area form an unmetamorphosed to low-rank metamorphosed, largely sedimentary sequence in excess of 25,000 feet thick. The strata have been separated into two successions that have been assigned tentatively to the Helikian and Hadrynian eras.

Helikian

Strata of probable Helikian age have been divided into seven formations. Bell (1968) studied the succession and the following descriptions are based largely on his report. The oldest rocks exposed have been assigned a Helikian age primarily on the basis of lithological similarity to the Purcell succession of the southern Rockies and, also, on the basis that they lie with profound unconformity (Pl. VI) beneath strata of known Early Cambrian age. Two other facts also indicate support for the Helikian age ascribed, though neither is diagnostic. First, the associated copper mineralization to date has been related inexplicably to sedimentary rocks of presumed middle Helikian (Purcell) age; and second, the occurrence of "molar tooth" structures in the carbonate has been noted only in rocks of middle Helikian age. "Molar tooth" structures

PLATE IV. Ordovician Kechika limestone unconformably overlying Helikian Tuchodi Formation. Silurian Nonda truncating Kechika limestones at right of figure 2 (note: gabbroic dykes cutting Tuchodi Formation at left side of figure 1).

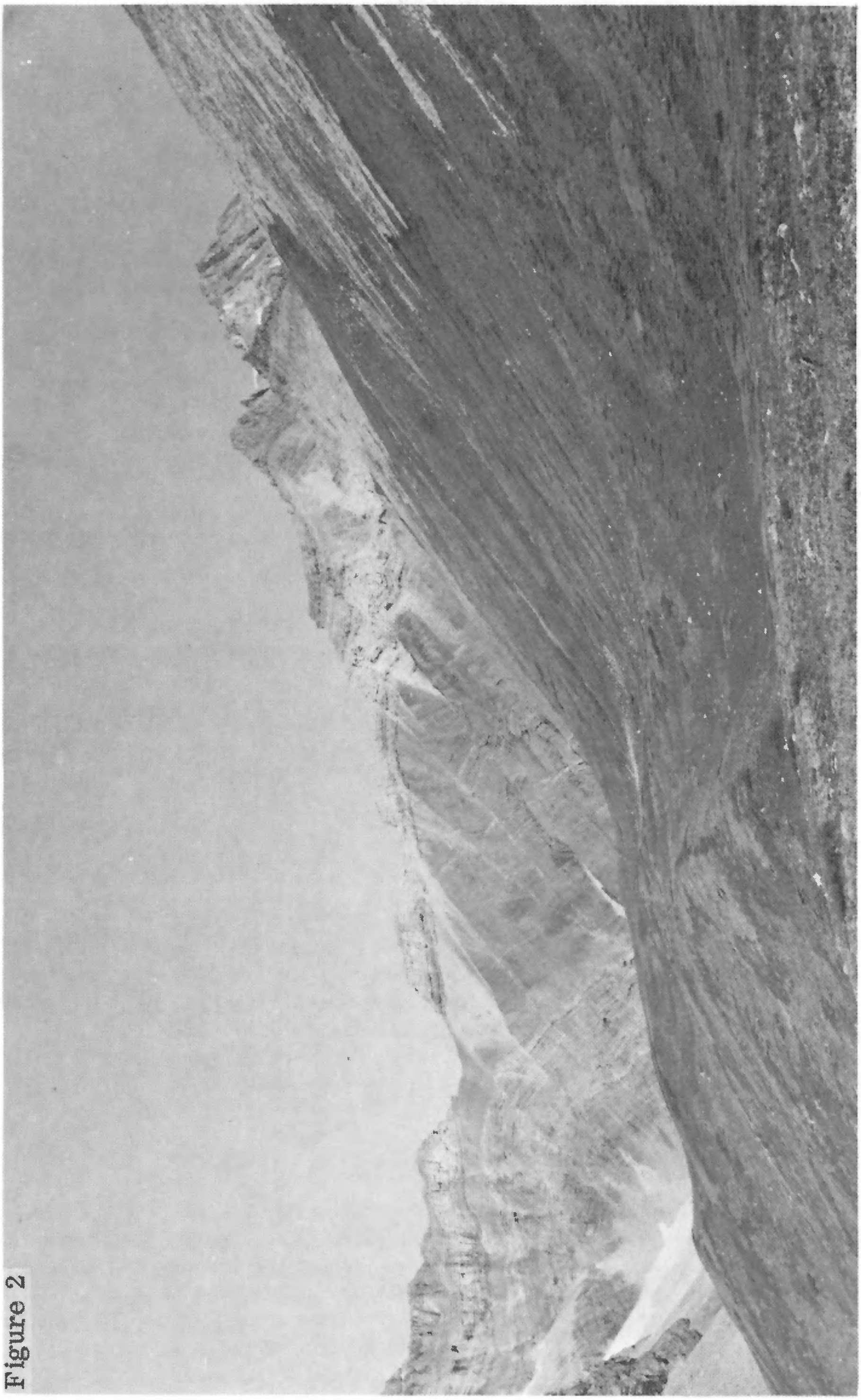

Figure 2

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PLATE V. Typical Tetsa Formation with basal orthoquartzites exposed on right side of photograph. George Formation carbonates overlying recessive Tetsa Formation on left (south) side of valley. Location: Bathtub Creek.

(Daly, 1912, p. 74: *see* Pls. VII, VIII) have been noted in the Siyeh Formation of both the Purcell System (Price, 1964) and the supergroup Belt (Childers, 1963); in the Little Dahl Formation of the Mackenzie mountains (Aitken, pers. com.); and in the Helikian of the Northwest Territories (Hoffman, pers. com.). All these formations are considered to be of middle Helikian age.

Chischa Formation

Beds assigned to the Chischa Formation are exposed only in the core of the Tuchodi Anticline. About 3,100 feet of strata are exposed in the core, but the base of the formation has not been seen.

Pale grey and pastel, aphanitic dolomite is the predominant rock type. Fine-grained orthoquartzites are common in the upper one-third of the succession. Stromatolites, "molar tooth" structure, desiccation breccias, and ripple-marks, common in the carbonate beds, suggest deposition in shallow water. Despite their great age, the rocks are little altered except where they are adjacent to the intrusive rocks.

The Chischa Formation is the oldest exposed unit within the map-area, and the existence of an unconformity at the top of the formation has been postulated by Bell (1968).

Tetsa Formation

The Chischa Formation is overlain unconformably by the Tetsa Formation which is exposed only in the core of the Tuchodi Anticline. Locally, north of Mount Mary Henry in the region now forming the east limb of the structure, the strata have been removed by pre-Silurian erosion. The formation is composed of about 1,050 feet of thin-bedded, dark grey to black, siliceous, feldspathic, micaceous and carbonaceous mudstone, siltstone, and shale. Several thin orthoquartzite units are present in the lower 200 feet (Pl. V). The upper beds of the Tetsa are dolomitic and gradational with the dolomite of the overlying George Formation.

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PLATE VI. Lower Cambrian Atan conglomerate unconformable on Helikian Tuchodi Formation.

George Formation

Carbonate rocks of the George Formation also are exposed only within the Tuchodi Anticline. The formation is 1,745 feet thick immediately south of Summit Lake and thins southward to 1,200 feet near Henry Creek. Along the east flank of the Tuchodi Anticline the formation has been removed by pre-Silurian erosion.

The George Formation consists of very finely crystalline limestone and dolomite. Stromatolitic beds, "molar tooth" structure, and desiccation breccias are characteristic of the unit. Much of the dolomite is secondary though conditions of deposition postulated for the beds are similar to those that produced primary dolomite in later systems.

Both lower and upper contacts of the formation are gradational. Bell (1968) has speculated that the upper contact may be significantly diachronous.

Henry Creek Formation

About 1,500 feet of calcareous mudstone overlying the George Formation has been assigned to the Henry Creek Formation which is exposed within the Tuchodi Anticline. The lower part of the formation is thought to be a facies equivalent of the upper part of the George Formation.

Slaty-cleaved, medium to dark grey, calcareous mudstone is the predominant rock type, though thin, very fine grained sandstone and limestone beds are present. The mudstone is commonly laminated and locally contains small black shale chips. Feldspar is a common component of the detrital fraction.

Both contacts of the formation are gradational. The number and proportion of sandstone beds increases upward in the upper part of the unit, and the beds are transitional with the sandstone of the overlying Tuchodi Formation.

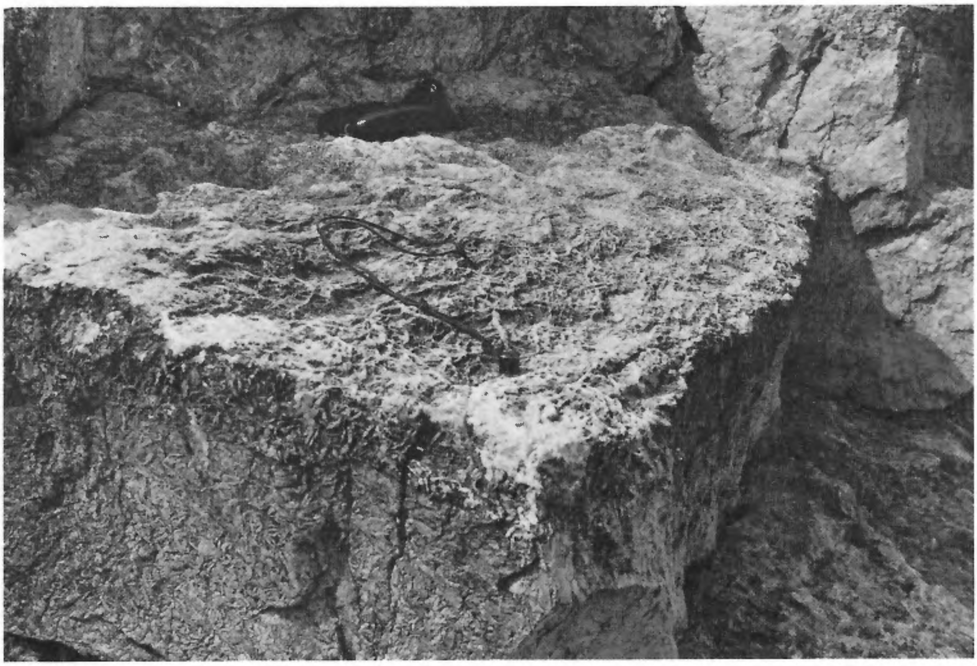

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PLATE VII. "Molar tooth" structure in outcrop of George Formation.

Tuchodi Formation

A succession of feldspathic quartzites, and silty and argillaceous dolomites, 5,000 feet thick, overlies the Henry Creek Formation and has been designated the Tuchodi Formation (Bell, 1968). Units of the formation are exposed on the flanks of the Tuchodi Anticline, and in the hanging-walls of the Sentinel and Petersen Thrusts. It is the most extensively exposed Proterozoic formation in the Tuchodi Lakes map-area.

The Tuchodi Formation is characterized by brown weathering feldspathic quartzite, and orange-brown weathering silty and argillaceous dolomite, and dolomitic siltstone. Sandstone and siltstone units are crossbedded and ripple-marked, commonly exhibiting mudcracked surfaces, and the dolomite is commonly stromatolitic, all features which suggest deposition in shallow water. Because dolomite is more common in eastern exposures, and the finer clastic units are more common in the western parts, shoaling conditions from west to east are indicated.

The Tuchodi Formation conformably overlies the Henry Creek Formation and is conformably overlain by the Aida Formation.

Aida Formation

Rocks assigned to the Aida Formation are exposed on the west flank of the Tuchodi Anticline and in the hanging-walls of the Sentinel and Petersen Thrusts. The formation is composed of calcareous and dolomitic mudstone and siltstone with minor amounts of sandstone. Its thickness ranges from about 3,400 feet near Tuchodi Lakes to about 6,600 feet near Churchill Peak. A convenient marker unit,

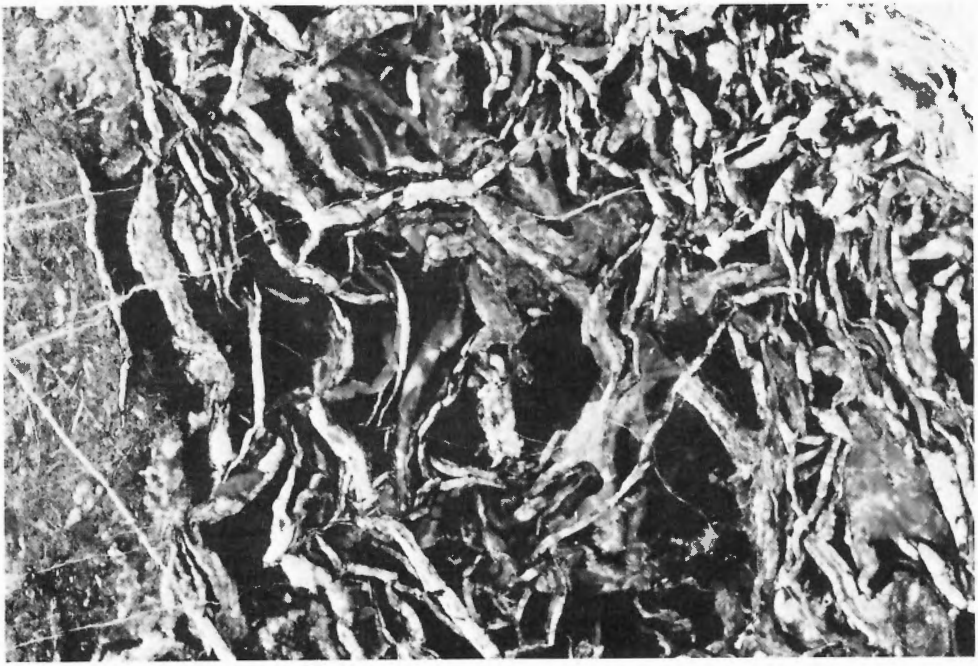

PLATE VIII. Polished specimen of "molar tooth" structure. Specimen 8 inches long.

consisting of 185 feet of green chamositic mudstone overlain by 200 feet of black carbonaceous mudstone, occurs 600 feet above the base of the formation. The calcareous mudstone commonly has slaty cleavage and exhibits structures characteristic of soft sediment deformation. Thin, graded beds of poorly sorted sandstone, and intraformational conglomerates suggest deposition in considerably deeper water than that being inferred for the time during which the Chischa through to Tuchodi Formations were being deposited.

The basal contact of the formation with the underlying Tuchodi Formation is sharp, but no evidence for an unconformity has been recognized. The top of the Aida Formation is conformable with the overlying Gataga Formation.

Gataga Formation

The Gataga Formation consists of dark slate exposed at the headwaters of Toad and Gataga Rivers between the Gataga and Gundahoo Thrusts. Several small remnants also are preserved east of Churchill Peak. The Gataga Formation is about 4,500 feet thick as preserved, but the top has not been seen. It consists mainly of dark grey to olive-grey mudstone and siltstone with slaty cleavage and very thin units of poorly sorted, graded, brown sandstone. Flame structures and laminations are commonly observed in the mudstone.

Throughout the map-area, the Gataga Formation is unconformably overlain by the Cambrian Atan Group with 5 to 15 degrees of angular discordance commonly observed.

Hadrynian

Rocks assigned to the Hadrynian era are exposed only west of the Gundahoo Fault, in the southwest corner of the map-area. This unnamed and undivided sequence is about 4,500 feet thick and consists of greenish grey, green and grey chloritic phyllites and slates with minor amounts of maroon slates, sheared greenstone lenses, and poorly sorted brown sandstones. These sediments have been metamorphosed to the low greenschist facies.

The upper contact of this succession appears to be conformable with the Cambrian Atan rocks. However, the argillaceous units within the Atan exhibit no evidence of metamorphism. Sixty miles to the south, the ?Hadrynian succession is in the low amphibolite metamorphic facies, and there also the overlying Cambrian is unmetamorphosed. Although the contact between the two has not been observed, a disconformity between the two successions is postulated. The Hadrynian succession is bounded on the east by the Gundahoo Fault, and nowhere is the base of the succession exposed, so that the relationship of the Helikian to the Hadrynian is uncertain. The two successions are presently separated by the Gundahoo Thrust on which there has been significant Laramide displacement. That displacement, relative to the overlying Cambrian succession is, however, insufficient to eliminate the discontinuity of the Proterozoic successions. It is, therefore, necessary to postulate major pre-Cambrian motion (sense ill-defined, though probably with a large strike-slip component) on the fault and subsequent reactivation of the fault during Laramide tectonism. Strata assigned to the Hadrynian are presumed to be younger than the succession assigned to the Helikian era, as no discordant basic intrusives were observed cutting the Hadrynian rocks.

Igneous Dykes

All formations assigned to the Helikian era are cut by steeply dipping gabbroic dykes composed of 40 to 50 per cent augite, 30 to 40 per cent labradorite (An_{55}), 4 to 8 per cent magnetite, and 2 to 4 per cent quartz. These dykes, commonly 20 to 50 feet thick but locally as much as 250 feet thick, are not known to cut rocks assigned to the Hadrynian era. Several greenstone bodies that exist as concordant elements within the Hadrynian succession may represent surface extrusions of which the dykes were the feeder channels. An upper age limit for the dykes can be determined because of their truncation against the sub-Cambrian surface and by the inclusion of cobbles and pebbles of dyke material in the Lower Cambrian conglomerates. Dykes were observed cutting, as well as occupying and welding the walls of pre-existing thrust, normal, and reverse faults.

Paleozoic

Within the Paleozoic succession, dominantly carbonate strata of Cambrian to Middle Devonian age, are succeeded by mainly clastic rocks of late Paleozoic age.

Cambrian

Atan Group

Rocks assigned to the Atan Group (Gabrielse, 1954) unconformably overlie Helikian rocks in the eastern exposures and are paraconformable with the Hadrynian strata west of the Gundahoo Fault. Two main facies have been mapped within the

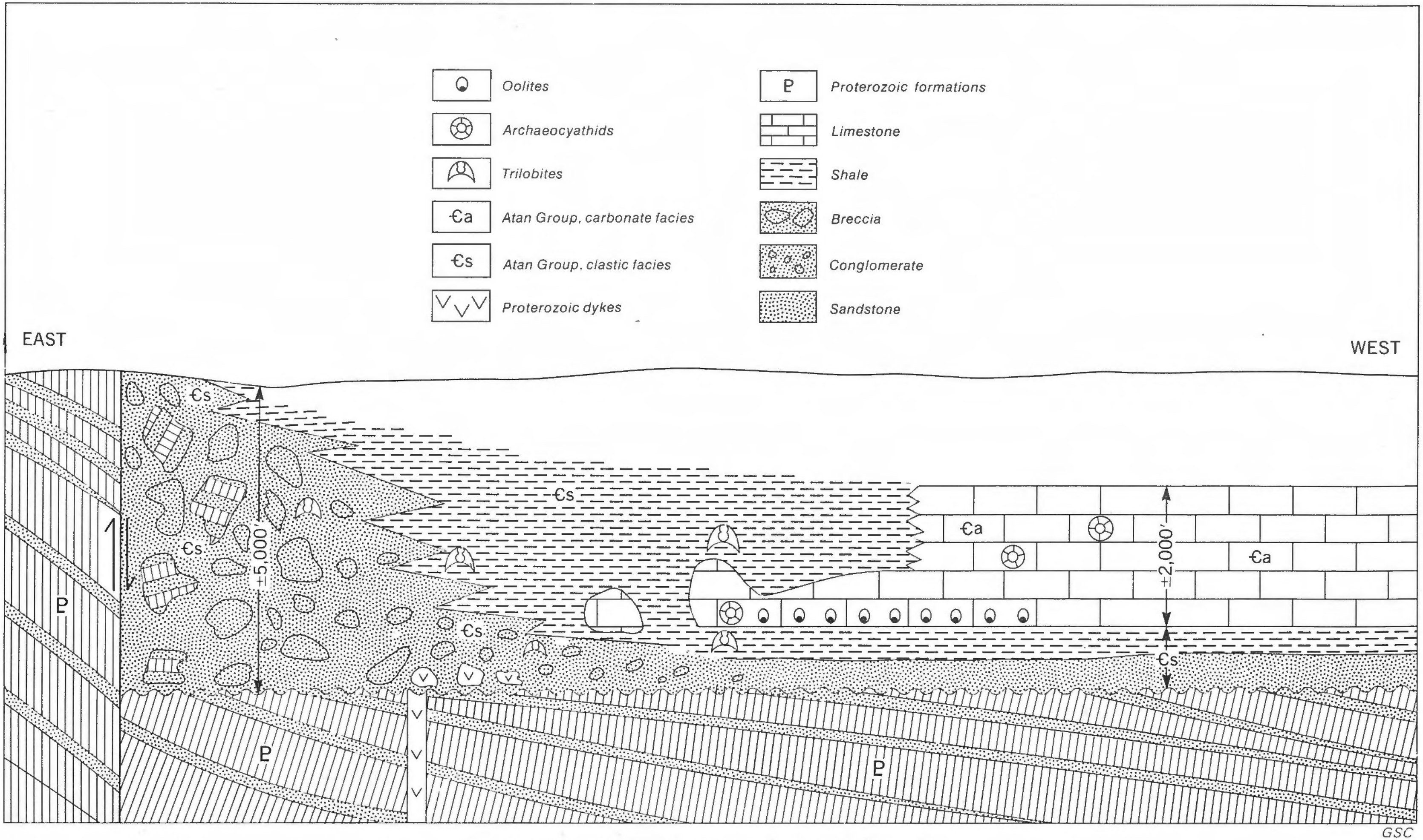

FIGURE 1. Schematic diagram of Lower Cambrian sedimentation.

Atan Group: an eastern and lower clastic facies, and a western, partly coeval carbonate facies (*see* Fig. 1). The Atan Group was largely removed from the region of the Tuchodi Anticline by pre-Ordovician erosion.

The thickness of the clastic facies ranges from a zero edge to more than 5,000 feet. The succession apparently represents large fanglomerates deposited adjacent to active faults. Near the fault traces, the fanglomerates are sheared, polymictic, very coarse, typically grey, and contain some boulders as much as 10 feet in largest dimension. At distances in excess of 2 miles from the fault traces, the strata are typically red, the maximum boulder size is markedly reduced, and only the more resistant quartzites form the clasts, which are moderately well rounded. The conglomerates pass laterally into siliceous quartzite with minor intercalated siltstone and silty shale. West of the Presidential Range, small reef-like mounds of archaeocyathid-bearing limestones mark the front of the carbonate platform of the Atan Group. Much of the carbonate occurs as limestone. Basal units in the carbonate sequence are commonly oölitic, whereas the upper units consist of fine-grained limestone.

The base of the Atan Group is late Early Cambrian in age. In the transition zone between clastic and carbonate facies units, the presence of both trilobites and archaeocyathids in, and typical of, their respective facies units provides a convenient cross-reference of the faunas. Material collected (GSC loc. 70472) from immediately below the main carbonate unit that lies just above the Gataga Thrust north of the West Toad River yielded the following fauna:

GSC 70472 *Bonnia* sp.
Chancia sp.
cf. *Corynexochides* sp.
cf. *Elrathina* sp.
Ogygopsis sp.
aff. *Onchocephalus walcotti* Resser, 1937
Pachyaspis sp.
Paterina sp.
Prozacanthoides? sp.
Syspacephalus sp.
archaeocyathids

W. H. Fritz (GSC Paleontology Report No. C4-1967-WHF), who identified the fauna, notes that typical late Early Cambrian specimens which were identified as *Bonnia* sp., aff. *Onchocephalus walcotti* Resser, 1937, *Prozacanthoides*? sp., and *Syspacephalus* sp. occur with the remaining trilobites that are known either mainly or exclusively from the Middle Cambrian. There is no question as to the natural association of the trilobite species, as they occur together in the same piece of rock. Fritz favours the late Early Cambrian assignment of the fauna because of the presence of *Bonnia* sp. which is considered one of the best late Early Cambrian index fossils, and because of the association with the archaeocyathids.

Ordovician

Kechika Group

An estimated 4,000 feet of strata occurring in the western part of the Tuchodi Lakes map-area has been assigned to the Kechika Group (Gabrielse, 1963). Four facies units have been mapped, but little detailed stratigraphy of the group has been attempted in the area. Pre-Silurian erosion removed all of the Kechika Group from the northeast half of the map-area and much of the strata over the rest.

Relatively clean, platform-type, shallow water limestone with minor amounts of intercalated orthoquartzite occurs east of the main drainage divide between the Trench and Foothills, and mainly to the south of the Alaska Highway. West of the divide, rocks of equivalent age occur in a graptolitic shale facies. The two units essentially correspond to the Mount April and Cloudmaker Formations exposed in the Ware map-area to the south (Jackson *et al.*, 1965). Results of regional study suggest that the carbonate platform overlaps the shale facies to the west. A third facies, which outcrops immediately to the northwest of Churchill Peak, consists of turbidites and separates the carbonate from the shale. North of the Alaska Highway and west of Muncho Lake the fourth facies unit, a thick sequence of argillaceous limestone, occurs as a widespread unit replacing both the platform carbonate and the graptolitic shale. This is the characteristic Kechika lithology of the type area. South of the Tuchodi Lakes map-area, thick units of volcanic sediments occur within the lower part of the graptolitic shale succession, and thin dykes and sills have been observed cutting the carbonate facies south of Redfern Lake. Local prospectors have reported copper mineralization associated with some of these dykes.

Within the Tuchodi Lakes map-area, the base of the Kechika Group is of very early Ordovician age. Fossils collected from 20 feet above the base from a section 4 miles southwest of the junction of Churchill and Delano Creeks have been identified by B.S. Norford as:

GSC loc. 57349 ?*Bellefontia* sp.
Symphysurnia sp.
Age: very early Early Ordovician, probably Zone B of Utah–Nevada sequence.

Another collection, 1,400 feet stratigraphically higher, was identified as follows:

GSC loc. 57305 inarticulate and orthid brachiopods
?*Kainella* sp.
Age: probably early Early Ordovician, possibly Zone D of Utah–Nevada sequence.

Both collections were made from the platform carbonate succession, where potentially younger representatives of the Kechika Group have been removed by pre-Nonda erosion. West of the Tuchodi Lakes map-area, Gabrielse (1963) reported a Middle Cambrian fauna from the Kechika Group of the McDame map-area. He subsequently (1967) reported the reassignment of a Late Cambrian age to this fauna. The presence of Late Cambrian strata to the west of, and the almost certain absence of such strata within, the Tuchodi Lakes map-area would suggest transgression of the Kechika seas from west to east. The interpretation of the facies distribution of the Kechika rocks also leads to a similar conclusion.

Silurian

Nonda Formation

The Nonda Formation (Norford *et al.*, 1966) is the lowest formation in a blanket of middle Paleozoic carbonate strata that covered much of northeastern British Columbia. It has been removed subsequently from most of the area southwest of the Roosevelt Thrust by post-Laramide erosion, and from much of the Interior Plains and Foothills regions beneath the sub-Devonian unconformity. Within the map-area the Nonda Formation thins from 970 feet at its type section immediately west of the Toad River bridge to 630 feet on the MacDonald Platform at Mount St. George, as a result of stratigraphic condensation and of pre-Devonian erosion. West of the outcrop belt of the Nonda Formation, rocks of equivalent age occur in a graptolitic shale facies. Within the graptolitic shale basin, Silurian strata older than the Nonda carbonates are known from immediately south of the Tuchodi Lakes map-area and are considered to be representative of the Sandpile Group of adjacent areas to the west. These rocks may extend into the extreme southwest corner of the map-area, but for convenience all the graptolitic shales have been included in that facies unit of the Kechika Group. The front of the Nonda carbonate-shale facies occurs as much as 5 miles east of the similar facies front of the underlying Kechika Group.

The Nonda Formation consists mainly of a succession of dull dark grey dolomites, however, quartz sandstone and orthoquartzite units are present at the base of the formation throughout most of the Tuchodi Lakes map-area. The dolomites are commonly medium crystalline and contain minor amounts of quartz sand and silt. They are thick bedded to massive; the bedding being prominent though the surfaces are irregular. Small dolomite-filled vugs are common and rare larger vugs occur only partly filled with dolomite and quartz. Tuberous chert nodules and silicified algal and stromatoporoidal beds are more common in the upper strata. Limestone is rare except at the type section where it constitutes a lower local member. In eastern sections, the thin orthoquartzite and quartz sandstone units in the main part of the formation suggest proximity to an eastern shoreline.

The structural pattern of much of the area includes numerous thrust faults, whose roots of décollement tend to be stratigraphically controlled by two stratigraphic intervals within the Nonda Formation. The first, and more common, comprises shaly beds within the basal sandstones of the formation; the second is a set of several zones near the top of the Nonda.

The Nonda Formation is of late Early Silurian age. Norford *et al.* (1966) record four faunal assemblages, all of which are probably late Llandoverian in age. Only the lower three of these assemblages are present in the type section, and the upper of these has been removed from the MacDonald Platform by pre-Devonian erosion.

Devonian

Muncho–McConnell Formation

The Muncho–McConnell Formation (Taylor and MacKenzie, 1970) has an outcrop distribution similar to that of the underlying Nonda Formation. Within Tuchodi Lakes map-area the formation thins from 890 feet at its type section where it overlies the type Nonda Formation to 345 feet on the MacDonald Platform near Mount St. George.

The formation consists of an alternation of medium and dark grey finely crystalline dolomites. Bedding is well developed and relatively uniform. Minor intercalated orthoquartzite units are common in eastern sections. Floating quartz sand, desiccation breccias, and other primary sedimentary structures indicate deposition in shallow water shoaling eastwards. Thin, varicoloured shales and shale partings are common in western exposures. The contact with the underlying Nonda Formation is sharp, marked by an abrupt change in colour from the more somber hued dolomites of the Nonda and by a recessive profile resulting from the presence of sandy and silty strata within the basal beds of the Muncho–McConnell Formation. This contact is the sub-Devonian unconformity, an erosion surface which, in the Tuchodi Lakes map-area, cuts stratigraphically downwards to the east.

Fossils are rare in the Muncho–McConnell Formation and most of those collected to date are not diagnostic. The most significant fauna recovered consists of Heterostracean fish fragments found southeast of Long Mountain in the Terminal Range (Gabrielse, 1962 a, b) and in the Trutch map-area just north of Keily Creek (Norford *et al.*, 1966). These fish remains have been dated by R. Thorsteinsson (pers. com.) as Early Devonian.

Wokkpash Formation

The Wokkpash Formation (Taylor and MacKenzie, 1970) overlies the Muncho–McConnell Formation and has a similar areal distribution within the Tuchodi Lakes map-area. The formation thins from 376 feet in the vicinity of Muncho Lake to 105 feet over the MacDonald Platform near Mount Mary Henry.

Over the MacDonald Platform, the Wokkpash consists predominantly of orthoquartzite and quartz sandstone. These quartzose rocks are thick bedded to massive and commonly strongly crossbedded. North, south, and west of the MacDonald Platform, the argillaceous and dolomitic content of the formation increases. Shrinkage cracks and desiccation breccias occur in several zones within the formation attesting to its deposition in shoal waters. Near Muncho Lake, small amounts of anhydrite and collapse breccia define a region of evaporite deposition. The Wokkpash conformably overlies the Muncho–McConnell Formation and is considered to be an upper and regressive facies of the Muncho–McConnell depositional episode.

No fossils have been found in the Wokkpash Formation. It has been assigned an Early Devonian age because it overlies known Lower Devonian strata and is, in turn, overlain by beds considered to be of either latest Early or earliest Middle Devonian age.

Stone Formation

The Stone Formation (Taylor and MacKenzie, 1970) overlies the Wokkpash Formation and has a similar areal distribution. The formation thins from 1,935 feet near Muncho Lake to 1,185 feet on the MacDonald Platform near Mount St. Paul.

Three facies units are recognized within the Stone Formation of northeast British Columbia: a sandy dolomite facies occurring mainly to the south of the Tuchodi Lakes map-area; an evaporite and dolomite breccia facies occurring along the mountain front near Summit Lake; and a western, bedded dolomite and limestone facies typical of the succession near Muncho Lake. The dolomite strata are most commonly very light grey, very finely crystalline to aphanitic, contain little clastic material, and are indistinctly bedded although the evaporite facies is commonly laminated. Rare intercalated beds of limestone are typically very dark grey, medium to coarsely recrystallized, and most contain relict structures suggestive of amphipora-like organisms. The lower contact of the Stone Formation with the Wokkpash is sharp and unconformable. On the MacDonald Platform a low-angle unconformity has been observed that is not recognizable elsewhere.

Fossils are very rare within the Stone Formation and most of those recovered are very poorly preserved and not diagnostic. The age of the formation is based largely on stratigraphic position. It overlies known Early Devonian rocks and is overlain by early Middle Devonian strata, therefore, it seems likely that the Early–Middle Devonian time boundary occupies a position within the Stone Formation. The presence of *Moellerita canadensis* near the base of the overlying Dunedin Formation suggests that the upper part of the Stone Formation is pre-middle to early Eifelian in age. Lower Devonian conodonts have been recovered from the lower part of the Stone Formation in the Toad River map-area to the north.

Dunedin Formation

The thickness of the Dunedin Formation (Taylor and MacKenzie, 1970), which consists of well-bedded limestone, ranges from 666 feet near Mount Mary Henry to 1,100 feet in the northwest near Muncho Lake. The formation caps the blanket-like Silurian to Middle Devonian carbonate rocks. Its areal distribution is similar to that of the underlying Stone Formation.

Carbonates of the Dunedin Formation are typically dark grey, argillaceous, micritic to fine-grained limestones. Near Muncho Lake, basal strata of the Dunedin Formation include units of very finely crystalline dolomite. Elsewhere, dolomite occurs only as stringers and vein fillings, or as small euhedral crystals in predominantly calcareous rocks. Tuberous nodules and thin, irregular beds of black chert are common only in the upper 200 feet of the formation.

The contact of the Dunedin with the underlying Stone Formation is variable. In eastern and southern sections the contact is sharp and disconformable. Locally, a thin regolith is preserved at the contact. The most obvious features are the abrupt change from dolomite below to limestone above, and the coincident marked colour change from light to dark grey. Near Summit Lake the contact is sharp also and is placed similarly according to the lithologic and colour change, but the unconformity, if present, is not obvious. To the west, near Muncho Lake, the contact is arbitrary and the succession apparently conformable.

The Dunedin Formation is of Middle Devonian age. Fossils collected from the top of the formation indicate that the top of the unit is diachronous. North of Muncho Lake the uppermost beds contain fossils of Eifelian age, whereas in the latitude of the Alaska Highway the faunas are typified by *Leiorhynchus castanea* of early Givetian age. The Dunedin Formation correlates approximately with the Hume and Nahanni Formations of District of Mackenzie and Yukon Territory.

Besa River Formation

The Besa River Formation (Kidd, 1962, 1963; *see* also Bamber *et al.*, 1968) outcrops in a narrow belt flanking the Stone Range and along the eastern margin of the Sentinel Range.

Within the Tuchodi Lakes map-area the Besa River Formation, in outcrop, is between 1,000 and 1,400 feet thick and consists almost entirely of black shales, variably siliceous, with lesser amounts of siltstone and limestone. The lower contact of the Besa River Formation is progressively older, and the upper contact progressively younger from southeast to northwest. This diachronism is caused by a lateral change from carbonate in the east to shale in the west in units of Devonian and Mississippian age.

Fossils are rare in the Besa River Formation. Upper Devonian conodonts, ostracods, foraminifers, brachiopods, and cricoconarids (tentaculitids) occur in the lower part of the unit at several localities. Middle Devonian fossils have not been found in the formation, but are present in transitional beds of the uppermost Dunedin Formation. The youngest fossils found in the Besa River Formation are Chesteran representatives of the ammonoid genus *Goniatites* from Smith River bridge on the Alaska Highway immediately west of the map-area.

Mississippian

Prophet Formation

The Prophet Formation (Sutherland, 1958) is a sequence of limestone, chert, and dolomite of Mississippian age. The formation is exposed in two discontinuous belts east of the Tuchodi Anticline within the Foothills region of the Tuchodi Lakes map-area (Bamber, *et al.* 1968). Maximum thickness of 300 feet occurs in the eastern belt, and the formation thins to 11 feet where last recognized near the headwaters of Dunedin River.

Bamber, *et al.* (1968) described an abrupt facies change from carbonate to chert and shale across a north-northwesterly trending line lying within, but slightly oblique to, the structural trend of the Foothills. At the latitude of the Alaska Highway, the carbonate facies does not outcrop and only the extreme western remnants of the Prophet Formation are exposed. The thin chert of the western facies could be confused with the Permian Fantasque chert, but the latter lacks the carbonate lenses that characterize the Prophet Formation. The Prophet Formation is not recognized within the Racing River Synclinorium.

No fossils have been found in the thin, western chert facies of the Prophet Formation. On Water Ouzel Creek, *Goniatites crenistria* Phillips (identified by W. W. Nassichuk) was collected from shale 78 feet above the top of the Prophet Formation. This species is early Chesteran in age, and the shale is therefore younger than the uppermost Prophet Formation of the type section.

Stoddart Formation

Only thin remnants of the Stoddart Formation are preserved within the Tuchodi Lakes map-area and, because of lithologic similarity, these strata have been mapped with the overlying Kindle Formation. Although both the Golata and Kiskatinaw–Taylor Flat Formations of the Stoddart Group could be recognized, they could not be mapped individually and have, therefore, been reduced to formational status. The Stoddart Formation is absent from the easternmost Paleozoic outcrops south of Chlotapecta Creek. At the western edge of the Foothills at Water Ouzel Creek, about 530 feet of beds assigned to the Stoddart are preserved beneath the Permian Kindle Formation.

The Stoddart Formation there consists of about 150 feet of shale, equivalent to the Golata Formation, overlain by a sequence of sandstone, shale, limestone, and siltstone. A similar sequence to the north near Dunedin River contains more abundant sandstone and the succession appears transitional to the Mattson Formation of the southern Yukon. The youngest known beds of the Stoddart Formation in the area occur one-half mile north of Mile 381.5 on the Alaska Highway. There, a fauna of probable Namurian (?early Pennsylvanian) age has been recovered.

Permian

Kindle Formation

The Kindle Formation (Laudon and Chronic, 1949) outcrops in a narrow belt paralleling the mountains proper. It ranges from 35 to 500 feet thick.

Three lithologic units are recognizable within the Kindle Formation in the Racing River Synclinorium. The lower unit consists of 130 to 200 feet of dark grey weathering siltstone with thin shale and calcareous siltstone beds. The middle unit, 70 to 100 feet thick, has a banded appearance which results from an alternation of dark grey weathering, argillaceous siltstone and orange weathering, calcareous and dolomitic siltstone. The upper unit consists of dark grey weathering, siliceous mudstone, shale, and some chert. Farther southeast in the Foothills, north of Tuchodi River, the Permian sequence beneath the Fantasque Formation contains beds of sandstone and siltstone with some intraformational conglomerate. Much of this sequence is very calcareous, and some coarse-grained fragmental limestone is present. The presence of these relatively coarse grained rock types and the abundance of calcareous material characterize the eastern facies of the Kindle.

Laudon and Chronic (1949, pp. 193, 210, Text-fig. 9a) report an unconformity at the base of the Kindle Formation at its type section. The nature of this contact elsewhere in the Racing River Synclinorium has not been established because of poor exposure. East of the Stone Range, the Kindle rests with obvious unconformity on rocks as old as Prophet Formation, the basal surface resting on progressively older rocks eastward.

The Kindle Formation is of Permian age. Bamber, *et al.* (1968) report that the middle, and upper part of the lower unit contain a few horn corals and a sparse brachiopod fauna. This fauna includes *Choristites* associated with Permian representatives of the genera *Pterospirifer, Waagonoconcha, Spiriferella,* and *Neospirifer.*

Fantasque Formation

The Fantasque Formation (Harker, 1961; Bamber, *et al.*, 1968) outcrops between Toad and Tuchodi Rivers. The formation is about 120 feet thick and consists of irregularly bedded, dark grey chert with minor shale lamellae. The chert is absent within the Racing River Synclinorium, but the upper dark grey, siliceous unit of the Kindle Formation may be a western facies equivalent of the Fantasque Formation.

The Fantasque chert lies disconformably on older Permian rocks. The disconformable contact is marked by an abrupt change in lithology and commonly shows relief of 6 inches or more. Between Chlotapecta Creek and Dunedin River Fantasque strata are underlain by a thin, irregular bed of shale containing numerous nodules and pebbles? of phosphatic material.

The Fantasque Formation is of Permian age. It contains few fossils other than sponge spicules. Poorly preserved productid brachiopods and *?Helicoprion* sp. have been collected from a stratigraphic position 81 feet below the top of the formation on Dunedin River.

Mesozoic

Triassic

Pelletier (1959, 1960, 1961, 1962, 1964) published the results of a detailed stratigraphic investigation of the Triassic formations of northeastern British Columbia that had in part been established by McLearn (1945). Tozer (1967) summarized the large amount of information relating to the Triassic faunas of the area.

Triassic formations, as used in this report, are effectively facies units. The formations maintain their character along the direction of depositional strike (approximately parallel with the tectonic strike), but change markedly across the strike into the depositional basin. Their contacts are significantly diachronous in east–west section, a feature recognized by both Pelletier (1964, p. 4) and Tozer (1967, p. 6). For mapping purposes, the following scheme of subdivision was used in the Tuchodi Lakes map-area. Toad and Grayling Formations were mapped as a single unit. East of the Stone

Range the Toad–Grayling is overlain by the Liard Formation; the contact between the two units being placed at the base of the first sequence of massive sandstones, which is coincident also with a colour change from the somber dark greys of the Toad rocks to the light brown and orange-brown of the Liard rocks. In sections near the headwaters of Dunedin River, the lower sands of the Liard Formation can be seen to pass literally into Toad-type siltstones. West of the Stone Range, the Toad Formation is overlain by a sequence of calcareous siltstone and sandstone distinct from the underlying Toad, but dissimilar to the Liard Formation (a very thin Liard can be recognized locally along the eastern margin of this belt). This sequence contains faunas much younger than those generally attributed to Liard assemblages, and has been correlated with the Ludington Formation (Gibson, 1971). Limestones at the top of this unit are lithologically similar to those of the Baldonnel Formation of the Peace River area. This sequence has been referred to as "post-Liard beds" by Pelletier and is here referred to as the Ludington Formation. Overlying the Baldonnel is the dark grey limestone of the Pardonet Formation.

Grayling Formation

Recessive, fine-grained sandstone and shale of the Grayling Formation are exposed rarely in the Tuchodi Lakes map-area, therefore, the Grayling Formation has been included with the overlying Toad Formation on the accompanying map. Pelletier (1961) reports an almost complete section exposed on the Dunedin River north of Milepost 384, Alaska Highway, where 881 feet of beds were assigned to the Grayling Formation. Within the Racing River Synclinorium, the Grayling Formation appears to be about 1,300 feet thick.

Typically, the Grayling consists of silvery weathering, noncalcareous, flaky shales, with thinly laminated, fine-grained sandstone units near the base. Small-scale sedimentary structures are common in the sands and Pelletier (Pelletier and Stott, 1963) interpreted them to indicate sedimentary transport to the southwest.

The Grayling disconformably overlies the Permian Fantasque chert. The contact with the overlying Toad Formation is gradational.

The Grayling Formation is Early Triassic in age. Fossils are rare but include Griesbachian bivalves and Dienerian ammonoids (Tozer, 1967).

Toad Formation

The Toad Formation conformably overlies the Grayling and is well exposed in draws on the higher ridges of the Foothills. The formation ranges in thickness from 1,200 feet in the eastern Foothills, to 3,000 feet in the Racing River Synclinorium, then decreases to 1,500 feet in the westernmost Foothills near the Sentinel Range.

The Toad Formation consists of dark grey weathering, calcareous siltstone and shale with prominent, thick, very fine grained sandstone units being common in the middle and upper parts of the formation. The contact with the overlying Liard Formation is placed at the base of the lowest prominent, massive, orange weathering sandstone. Near the headwaters of Dunedin River, three prominent ribs of typical Liard-type sandstone are separated by typical Toad-type dark siltstone. Westward, these sandstone units pinch out so that the Toad–Liard contact rises stratigraphically. The diachronous nature of this contact is further indicated by the occurrence of *Nathorstites,* a typical "Liard" fossil, in strata of typical Toad lithology in these western exposures.

The Toad Formation is of Early and Middle Triassic age in the Tuchodi Lakes map-area, and contains faunas of Smithian, Spathian, Anisian and Ladinian age. The upper age limit of the formation varies with geographic location within the map-area, the formation being diachronous in an east-to-west direction with younger sediments occurring in western sections. Tozer (1967, p. 68) illustrates a section 10 miles north of Tuchodi Lakes containing faunas as young as the *Sutherlandi* Zone (Ladinian) from rocks he assigned to the Liard Formation but which Taylor assigns to the Toad Formation. Similarly, the lower limit varies with geographic location and, within the Tuchodi Lakes map-area where Grayling Formation is recognized, the oldest fauna assigned to the Toad belongs to the *Tardus* Zone (Smithian).

Liard Formation

The Liard Formation conformably overlies the Toad Formation and is well exposed in the eastern Foothills where it caps most of the higher ridges. In the extreme northeastern corner of the Tuchodi Lakes map-area, pre-Cretaceous erosion removed the Liard Formation, and there shales of the Fort St. John Group lie directly on the Toad Formation. Within the Racing River Synclinorium, only thin units of sandstone are assigned to the Liard Formation. There, much of the strata equivalent to the lower Liard Formation is assigned to the Toad Formation on the basis of facies change; overlying rocks, which are in part younger, have been assigned to the Ludington Formation.

The Liard Formation has a maximum thickness of about 600 feet near the headwaters of Dunedin River. The formation consists of dark grey, massive siltstone, fine- to coarse-grained, orange weathering calcareous sandstone, and minor amounts of grey limestone. Large "cannon ball" concretions are common in the sandstone. Pelletier (1961), on the basis of sedimentary structures, infers a southwesterly direction of sediment transport.

The Liard Formation is of Middle Triassic age. It contains ammonite faunas of early Ladinian (*Poseidon* Zone) to late Ladinian (*Sutherlandi* Zone). The base of the formation is diachronous, with sands of the Liard passing westerly into the dark silts of the Toad Formation. This relationship is well exhibited in exposures near the headwaters of Dunedin River, where three tongues of characteristic Liard-type sandstone are separated by typical dark grey Toad siltstone. An upper age limit for the Liard cannot be given since, over most of the area where the Liard is best developed, pre-Cretaceous erosion has removed some of the record. The youngest fauna of the Liard yet identified belongs to the *Sutherlandi* Zone.

Ludington Formation

Strata assigned to the Ludington Formation (Gibson, 1971) were formerly referred to by the informal name "Grey Beds", by Pelletier (1964) and Tozer (1967). With the probable exception of an area around Gathto Creek, the Ludington Formation is confined to the Racing River Synclinorium within the Tuchodi Lakes map-area. The thickness of the formation ranges from 300 to 1,500± feet.

The Ludington Formation consists of fine-grained calcareous siltstone, sandstone, and lesser amounts of limestone, and commonly weathers to a light tan. Bedding is uniform and relatively thick and the strata are resistant, capping most of the higher ridges. In most sections, the contacts are sharp and apparently conformable. The westernmost occurrence of these strata, south of Milepost 428 on the Alaska Highway, is conglomeratic at the base and may unconformably overlie the Toad Formation.

There the unit is apparently conformably overlain by limestones of the Pardonet Formation. However, immediately north of the report area, limestone equivalent to the Baldonnel Formation occurs between the Ludington and Pardonet Formations. The apparent absence of the Baldonnel in the Tuchodi Lakes map-area is probably the result of facies change to Ludington-type strata.

The Ludington Formation in this area contains Karnian ammonoids in its lower and middle parts.

Pardonet Formation

Strata assigned to the Pardonet Formation are known from only one locality within the Tuchodi Lakes map-area. They cap the high hill lying to the south of Milepost 428 on the Alaska Highway. There, dark grey, thin-bedded limestone and calcareous siltstone overlie the Ludington Formation. Ammonoids of the Karnian and Norian stages are present as well as the guide fossil *Monotis subcircularis.*

Cretaceous

Cretaceous rocks, occurring in the northeastern corner of the map-area, include two sequences of marine shale separated by coarse alluvial to deltaic sediments. The Lower Cretaceous marine shale, assigned to the Fort St. John Group, is overlain gradationally by Upper Cretaceous conglomerate and carbonaceous shale and siltstone of the Dunvegan Formation. The latter lies disconformably below Upper Cretaceous marine shales of the Kotaneelee Formation.

Lower Cretaceous

Fort St. John Group

Lower Cretaceous marine shale and sandstone are included in the Fort St. John Group. In the Tuchodi Lakes map-area, the group comprises, in ascending stratigraphic order, the Buckinghorse, Sikanni, and Sully Formations. No continuous section is known but the thickness of the group probably is in the order of 5,500 feet.

The group overlies the Triassic Liard sandstone in exposures at Mile 375 on the Alaska Highway. Farther east and north, it lies on the older Triassic Toad Formation. The unconformity represents a major erosional episode that resulted in the bevelling of the underlying rocks in a northward and eastward direction.

Buckinghorse Formation

The Buckinghorse Formation (Hage, 1944) includes a thick sequence of dark grey to black, marine shale. It extends northward from Tetsa River, underlying a broad low area bounded on the east by the Dunedin escarpment and on the west by higher ridges of the outer Foothills. The most continuous exposures are on Tetsa River where about 2,100 feet of the lower part of the formation were measured (Stott, 1967, sec. 64-3). The formation was penetrated just below its contact with the Sikanni Formation in Pacific SR Can Del Kledo c-14-G/94-J-13, and its thickness there is in the order of 3,500 feet. Only small isolated outcrops were observed along McLellan Creek and along the outer Foothills.

The basal contact of the Buckinghorse Formation with Triassic Toad strata is present on Tetsa River (*see* Stott, 1967, sec. 64-3) and the lower 200 feet are well exposed at Mile 375 on the Alaska Highway. At the latter locality, the basal 9 feet comprise conglomerate, argillaceous sandstone with some disseminated pebbles, and interbedded, silty mudstone.

In the Tetsa region, the Buckinghorse is divisible into three parts which are roughly equivalent to the Garbutt, Scatter, and Lepine Formations of the Liard region to the north (*see* Stott, 1968). The lower 900 feet of the formation contain silty, rubbly to blocky shale containing some sideritic concretions and a few thin seams of bentonite. Those beds are overlain by 500 feet of interbedded platy to flaggy siltstone and silty shale, apparently equivalent to the lower part of the Scatter Formation. The upper shale is exposed in several gullies on the Dunedin escarpment and, although not examined in detail, is probably similar to that described on the east side of Muskwa River a few miles to the south (Stott, 1967, sec. 64-25). The uppermost beds of concretionary mudstone are transitional into the overlying sandstone of the Sikanni Formation and the contact is well exposed at Mile 351, a few miles beyond the eastern border of the map-area.

The type Buckinghorse Formation is Early to Middle Albian in age (*see* Stott, 1967, 1968). In the Tetsa region, the basal beds may be equivalent in part to the older Gething Formation. The Buckinghorse is overlain by the Late Albian Sikanni Formation. The Buckinghorse is correlated with the Moosebar, Gates, and Hasler Formations of upper Peace River; the Spirit River, Peace River, and Lower Shaftesbury Formations of the Plains; and the Garbutt, Scatter and Lepine Formations of the Liard region.

Sikanni Formation

The Sikanni Formation (Hage, 1944; Stott, 1960) consists of a series of sandstone units separated by intervals of silty concretionary mudstone. Although the formation was defined some 100 miles to the southeast on Sikanni Chief River, it is best developed along the Dunedin escarpment. Two sections were measured in the Tuchodi Lakes map-area, the more southerly one (64-4) being 819 feet thick and the other (64-6), 909 feet thick.

The lower beds of the Sikanni are transitional into the underlying Buckinghorse sediments. Although the upper boundary lies at different stratigraphic levels in other areas (*see* Stott, 1967, 1968), the upper boundary within this map-area appears to lie above a persistent sandstone sequence and to maintain a fairly constant position.

The sandstone units of the Sikanni Formation are fine grained, finely laminated, brown to grey, and brown weathering. Bedding is flaggy to thick bedded. The shale units are silty, dark grey to black, rubbly to blocky and contain sideritic concretions. Intervals of shale are more common in the lower two-thirds of the formation. A more continuous succession of sandstone occurs in the upper part.

As discussed previously (Stott, 1968), the Sikanni Formation contains a fauna of the *Neogastroplites* Zone of Late Albian age (*see* Jeletzky, 1964). It is equivalent to the Goodrich Formation of Pine River region.

Sully Formation

Marine shale lying between the Sikanni and Dunvegan Formations is included in the Sully Formation (Stott, 1960) which forms a recessive unit commonly covered by talus or vegetation. This shale is fairly well exposed east of the map-area on the south slope of Steamboat Mountain where it is about 275 to 300 feet thick. That thickness appears to remain fairly constant along Dunedin escarpment, but only a few isolated outcrops were observed.

The lower boundary has not been observed in this region but seems to be abrupt, with a marked change from Sikanni sandstone to shale. The upper beds are gradational into the overlying sandstones of the Dunvegan Formation.

The Sully Formation, lying between the Late Albian Sikanni Formation and the late Cenomanian Dunvegan Formation, is dated as latest Albian to early Cenomanian. The basal shale strata of the formation in the type region in the District of Mackenzie and also at Sikanni Chief River are apparently represented in Tuchodi Lakes map-area by the upper Sikanni sandstone. Therefore, the base of the Sully Formation in this region is presumably younger than at the type locality and the total interval may represent only early Cenomanian (earliest Late Cretaceous). The Sully is correlated with the Cruiser Formation of the Pine River region and with the upper Shaftesbury shale of the Plains.

Upper Cretaceous

Dunvegan Formation

The succession of Upper Cretaceous sandstone, conglomerate, and carbonaceous mudstone is assigned to the Dunvegan Formation (Dawson, 1881). Some of the most complete sections occur in Tuchodi Lakes map-area east of Dunedin River and McLellan Creek. Throughout most of the region, the upper surface of the formation is erosional and a complete thickness is unknown. On Dunedin River (Stott, 1968, sec. 65-4) the thickness is at least 548 feet.

The basal Dunvegan sandstone is fine grained, siliceous, and thick bedded to massive. The only occurrence of conglomerate in that unit was observed along the rim of Tsoo Tablelands north of Kledo Creek, immediately beyond the eastern border of the map-area. The upper part of the formation contains three major sequences of conglomerate and conglomeratic sandstone separated by carbonaceous mudstone. The pebbles are composed dominantly of quartz, quartzite, and chert of various shades of green, blue, grey, white, and black. They are rounded to well rounded and range in size from one-eighth to six inches in diameter.

The Dunvegan Formation of Peace River is considered to be late Cenomanian (McLearn and Kindle, 1950; Bell, 1963) and in neighbouring areas contains a flora dated by Bell as being of that age (*see* Stott, 1968).

Kotaneelee Formation

Small areas in the northeastern corner of Tuchodi Lakes map-area, covered by trees and vegetation, have been mapped as underlain by Kotaneelee Formation although no exposures were found. Areas having similar topographic expression and lying within the Liard Syncline in Toad River map-area and Maxhamish map-area are known to be underlain by Kotaneelee shale. It is reasonable to expect that small erosional remnants are present in the Tuchodi Lakes area.

The Kotaneelee Formation comprises dark grey to black, concretionary marine shale of Santonian age (*see* Stott, 1968) which lies with marked hiatus on the Cenomanian Dunvegan conglomerates.

STRUCTURE

The structural style of rocks within the Tuchodi Lakes map-area differs significantly from the model proposed for the southern Rocky Mountains where Price and Mountjoy (1971) have proposed that 125 miles of northeastward allochthonous transport occurred along an imbricate array of interleaved thrust faults above an undeformed passive crystalline basement during Laramide tectonism. In the northern Rockies the total amount of shortening appears to be much less and the style of deformation quite different. Folding and faulting seem to have been concurrent, with as much supracrustal shortening attributable to the former as to the latter during Laramide tectonism. This different structural response can be attributed directly to differences in the stratigraphic column. Unlike the areas to the south, the stratigraphic column is punctuated by angular unconformities (*see* Fig. 2) and has a greater diversity of lithologic types. In addition, Proterozoic sediments extend at least as far east as the mountain front and probably for some distance under the adjacent Foothills. All of the pre-Silurian strata were intensely and repeatedly deformed during earlier pre-Laramide periods of tectonism. This has, in effect, produced a pseudo-basement where bedding has been destroyed as a single directionally preferred element of anisotropy. This earlier tectonic history also undoubtedly resculptured the crystalline basement–sedimentary rock interface from a simple, west-dipping planar surface along which subsequent décollement and translation could be expected.

The pseudo-basement of previously deformed sediments was overlain by four additional gross lithologic successions (packets) separated by detachments, all of which were deformed during the Laramide Orogeny. The detachment surfaces isolated each packet from vertically adjacent packets allowing them to deform internally and disharmonically, each in a style consistent with its own mechanical restrictions. Consequently, only rarely can a set of structures be interpreted accurately by observing the structure in an adjacent "packet". Of the five packets recognized on the basis of structural style, two comprise strata of the Mountains, and the remaining three of the Foothills and adjacent Plains.

A fracture zone of very late normal faults is the only set of structures that does not readily fit into any structural synthesis. This zone was first mapped by Gabrielse (1962b) near Forcier Lake in the Rabbit River map-area. The zone extends southward from there along Trout River, in the Toad River map-area, entering the Tuchodi Lakes map-area beneath Muncho Lake. Faults of this system extend south from beneath Muncho Lake, down Petersen Creek into the valley of Toad River. These normal faults have as much as 2,000 feet of vertical displacement and produce a half-graben structure.

Rocky Mountains

The lowest structural packet observed comprises Proterozoic through Ordovician strata, and includes three major unconformities (*see* Fig. 2). Early tectonic activity is

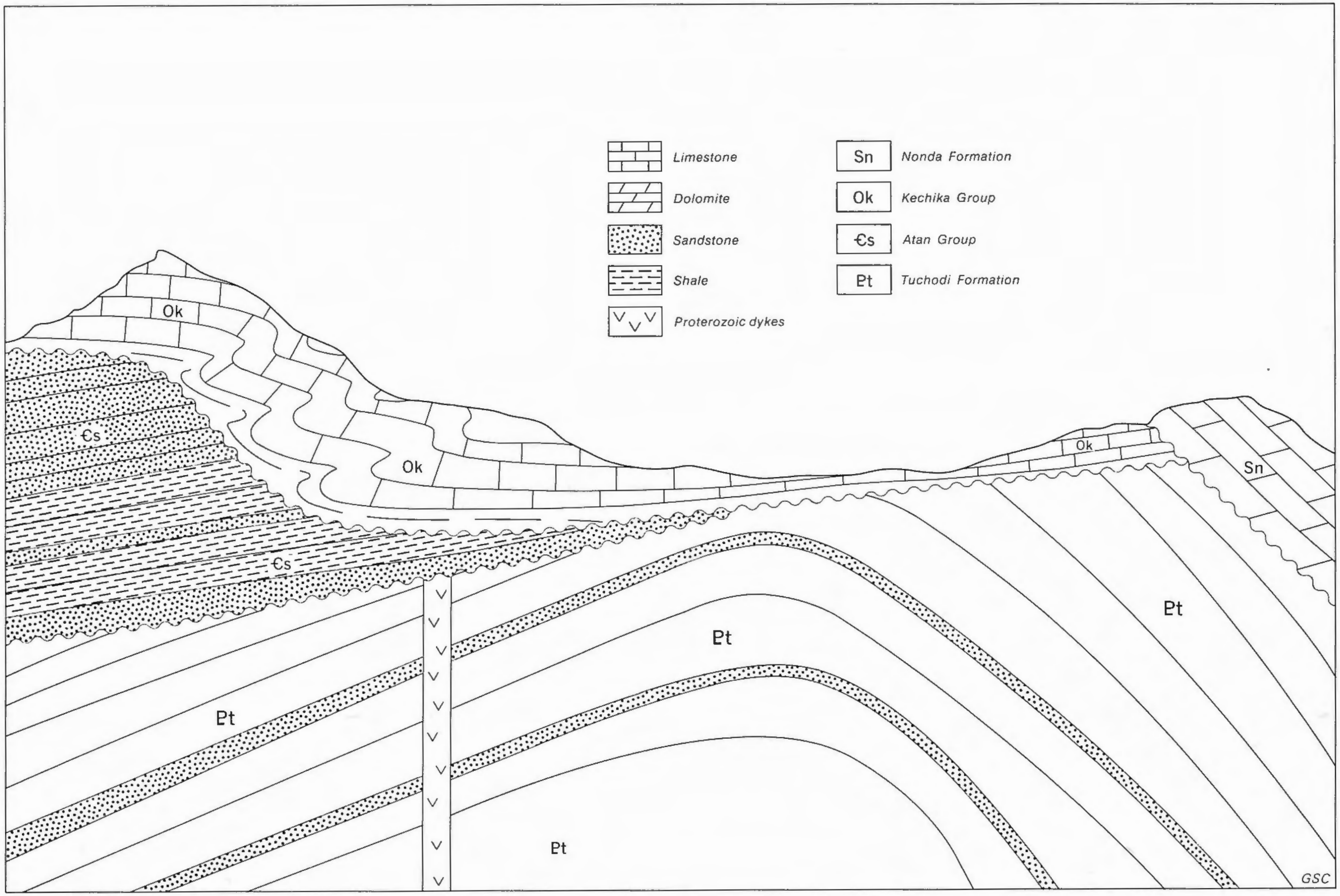

FIGURE 2. Schematic diagram of effects of early tectonism on the pre-Silurian strata as observed near Yedhe Mountain.

indicated within the Helikian strata by the presence of reverse, thrust, and normal faults, all pre-dating pre-Lower Cambrian dyke intrusion. In addition, the Hadrynian strata abut Helikian rocks along the Gundahoo Thrust. The displacement of the Cambrian contact on this fault is much less than that required to rationalize the Precambrian stratigraphic relationships, implying that much of the displacement (probably dextral slip) on this fault pre-dated Cambrian deposition, and that the fault was subsequently reactivated during Laramide deformation.

Lower Cambrian sediments also record substantial tectonic activity (*see* Fig. 1). The bulk of the sediments occur as fanglomerates derived from active fault blocks. Locally, near the faults, as much as 7,000 feet of conglomerate occurs, but it passes laterally into more normal marine sediments. South of the east end of Tuchodi Lakes, one such normal fault with about 5,000 feet of vertical displacement is overlain by unbroken Ordovician strata. Where these faults had a suitable trend, they were reactivated as reverse faults during the Laramide deformation. The contact of the Lower Cambrian with Helikian strata commonly exhibits an angular discordance in excess of 40 degrees.

Ordovician strata rest with angular unconformity on Cambrian and Helikian strata which were deformed, also predominantly by folding, prior to the deposition of the overlying Silurian carbonates.

Thus, in northeastern British Columbia, as typified by the Tuchodi Lakes map-area, there is a situation that differs significantly from that in the southern Rockies. Here, overlying the crystalline basement, there is a thick packet of sedimentary rocks that has had a complex early tectonic history. The concept of the single response to structural deformation of a heterogeneous succession of strata is not applicable. Nor, in the light of the early tectonism, can the sedimentary–crystalline rock interface be regarded as a relatively planar west-dipping surface along which subsequent décollement is probable.

This lowest structural packet was again deformed during the Laramide Orogeny into a series of large asymmetric folds with the east limbs of the anticlines commonly impinging on their adjacent synclines along steep reverse faults. Commonly these faults extend into the Nonda detachment surface where the shortening is accommodated by décollement movements of the overlying cover. These folds, such as the Tuchodi Anticline, have been elevated as much as 20,000 feet in structures not accompanied by observable faults. The possibility of crystalline basement involvement, rather than basal décollement, in these structures must be considered.

Unconformably overlying this first packet is a 7,000-foot-thick blanket of Silurian to Devonian shallow water carbonates forming the second discrete packet of rocks. This succession is analogous in physical characteristics to, though thinner than, the miogeosynclinal succession in the southern Rockies. Within this packet numerous bedding plane thrust faults are developed. These thrusts rise out of a detachment near the base of the Nonda Formation and disappear in a zone of detachment low in the Besa River Formation. The carbonate blanket apparently "floated" on the underlying packet, deforming concurrently but, in its own specific mode, quite disharmonically to the underlying succession. Excellent examples of these thrusts having roots in the décollement are exposed (*see* Frontispiece and Pl. IX) on both limbs of the Tuchodi Anticline as well as on Mount St. George which occupies the nose of that structure. This type of thrust is common over the structural depressions of the underlying packet producing a cascade effect of these faults. An example of the complexity of these structures (Pl. IX, figs. 1 and 2) is seen northeast of the junction of Delano Creek and Racing River. Followed from the east, the thrust is observed to dip westward, then flatten, and then to dip eastward. At this point movement on the fault stopped and subsequent deformation resulted in folding and truncation of the fault itself. Westward, during later phases of transport, the fault developed numerous splays. Traced farther west, the fault disappears into a detachment surface that occurs within the carbonate strata. The carbonates containing the detachment are involved in a major anticlinal fold having older rocks in its core that were not involved in the thrusting.

Rocky Mountain Foothills

The separation of the Foothills from the Rocky Mountains closely coincides with the structural level at which the Middle Devonian carbonates are exposed. With rare exception, the Foothills are composed of Upper Devonian and younger rocks.

Two families of folds occur within the Foothills. The lower family, or third structural packet, occurs in rocks of Devonian through Permian age. Detachment zones low in the Besa River Formation and low in the Grayling Formation bound the packet. The folds are commonly strongly asymmetric, of short wavelength and low amplitude, and show marked disharmonic relationships with the underlying structures. Thrusts in the underlying carbonates are dissipated by mechanical flowage within the Besa River shale and the supracrustal shortening is accommodated by the folding. Only in the eastern Foothills, where the Prophet Formation carbonates are well developed, is there a dominant structural member within the packets. There, the formation of large box folds is characteristic and reverse faults of small displacement are developed. These are among the very few observable faults within the Foothills.

The second family of folds, or fourth structural packet, is bounded by detachments low in the Grayling and Buckinghorse Formations. In the eastern Foothills, sandstone of the Liard Formation is the dominant mechanical member of the packet. The folds produced are long, *en échelon,* compound cylindrical folds. The relatively steep dips combined with only moderate structural relief require detachment at rather shallow depths. Within the Racing River Synclinorium, the dominant mechanical element is the thicker Ludington Formation, and consequently both the wavelength and amplitude of the folds are greater, although the style of deformation is similar to folds in which the Liard Formation is the dominant member.

Interior Plains

The western limb of the Liard Syncline, as outlined by the exposure of the Sikanni Formation, is used generally to define the western boundary of the Interior Plains. Very long wave folds of significant amplitude underlie the Plains. The abrupt change in style of deformation of the later Cretaceous rocks suggests detachment from the underlying structures at some ill-defined level within the Lower Cretaceous Buckinghorse Formation.

Summary

The structural style of the northern Rocky Mountains is quite different from that of the southern Rocky Mountains. This can be attributed, in part, to complex earlier periods of tectonism. Five internal structural packets have been recognized based on

PLATE IX

Figure 1. Thrust fault rooting in detachment zone near base of Nonda Formation. Location: west wall of MacDonald Creek valley, 3 miles south of Alaska Highway.

LEGEND

Dd: *DUNEDIN FORMATION*
Ds: *STONE FORMATION*
Dw: *WOKKPASH FORMATION*
Dm: *MUNCHO-McCONNELL FORMATION*
Sn: *NONDA FORMATION*
Ok: *KECHIKA FORMATION*
Pt: *TUCHODI FORMATION*

Geological boundary (approximate) . . . .
Thrust fault (approximate position; arrow indicates relative movement) . . . .
Detachment surface (approximate position) . . . . . .

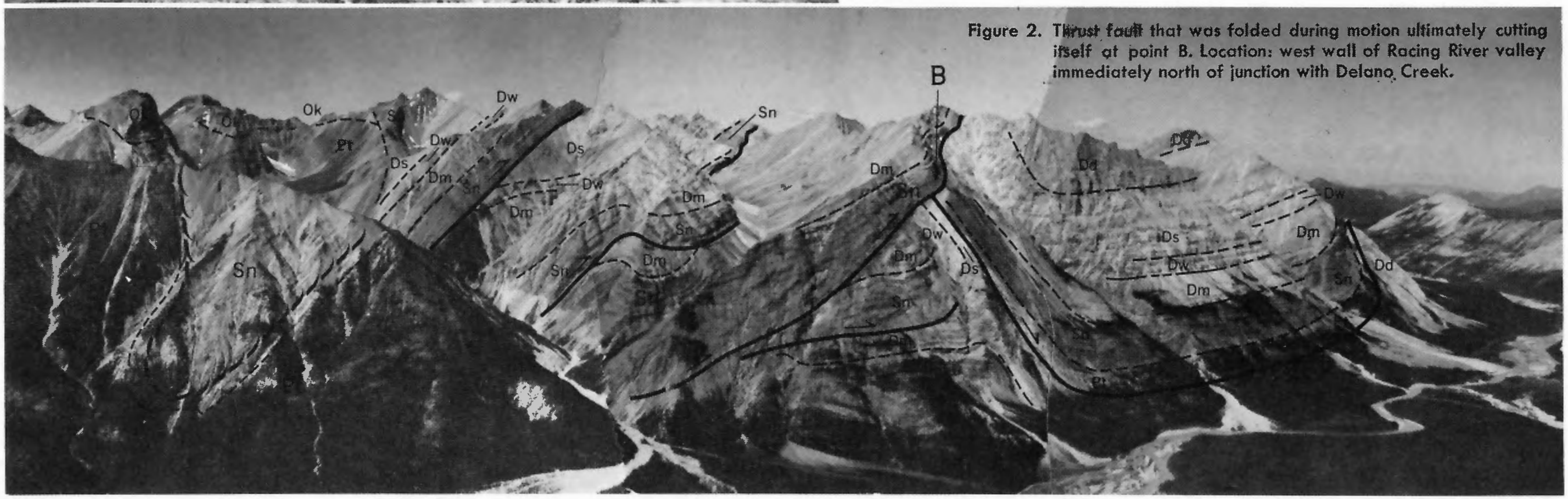

Figure 2. Thrust fault that was folded during motion ultimately cutting itself at point B. Location: west wall of Racing River valley immediately north of junction with Delano Creek.

the response of each to deformative forces. No direct continuum of structural types can be observed in vertical succession, yet the amount of deformation in vertically adjacent packets can be approximately compensated for by the different mechanisms of deformation. Only rarely does the particular style of structure of one packet carry through to an adjacent packet.

ECONOMIC GEOLOGY

Petroleum and Natural Gas

No petroleum or natural gas is produced yet from within the map-area nor have any wells been drilled to test the potential. Currently, natural gas is being produced from Devonian rocks in areas immediately to the east, but it is doubtful if rocks of that age occur in a similar facies within the map-area. Devonian, Mississippian, and Triassic limestone in outcrop all produced the fetid odour of gas when struck, but the proper combinations of porosity and entrapment have yet to be discovered.

Barite and Fluorite

Barite, commonly associated with fluorite, has been observed in the Middle Devonian carbonates at numerous localities. Barite must have been introduced into the sediments at least twice, since barite cobbles occur as lag deposits on the erosion surface developed at the top of the Wokkpash Formation, and because this mineral also occurs as massive bedded deposits near the base of the overlying Stone Formation. A third type of occurrence is a vein deposit within the Stone and Dunedin Formations. Most of the fluorite appears to be associated with this latter type of deposit. To date there has been no commercial production from these deposits although exploration activity has increased.

Copper

Copper, most commonly occurring as chalcopyrite, has been observed in several localities. In recent years, exploration has been active, with the result that one mine is being brought into production. The copper mineralization exists in vein deposits associated with basic dykes in the Helikian sedimentary rocks. Many of the showings seem to be located stratigraphically low in the Aida Formation, however, a great many deposits occur at other stratigraphic horizons. The Churchill copper deposit is located near the headwaters of Delano Creek. Carr (1971) reports the proven and probable ore reserves to be 1,178,000 tons having an average grade of 3.9 per cent copper.

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