GEOLOGICAL SURVEY OF CANADA
DEPARTMENT OF ENERGY, MINES AND RESOURCES, OTTAWA

BULLETIN 249

UPPER CRETACEOUS STRATIGRAPHY, YUKON COASTAL PLAIN AND NORTHWESTERN MACKENZIE DELTA

F. G. Young

1975

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Price - Canada: $6.00
Other Countries: $7.20

Catalogue No. M42-249

Price subject to change without notice

Information Canada
Ottawa
1975

PREFACE

Upper Cretaceous strata, important because of their coal and hydrocarbon reserves, comprise the youngest rocks of the Yukon Coastal Plain. They are overlain by sediments of Tertiary age under northwestern Mackenzie Delta and adjacent Beaufort Sea.

In this report, the author establishes the nomenclature, describes the stratigraphy, and presents evidence to support his conclusions regarding the regional correlations of Upper Cretaceous formations exposed on Yukon Coastal Plain and penetrated in boreholes on Mackenzie Delta. Included, also, are descriptions of the sedimentology and petrography of rock-units which form the beginnings of a wedge of molasse-like, clastic strata that is ancestral to modern sedimentation in the Mackenzie Delta. This stratigraphic and lithologic information is important for an understanding of the geological history of the Beaufort-Mackenzie Basin, and for determining its potential with respect to reserves of natural gas, petroleum and coal.

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ABSTRACT

Upper Cretaceous strata comprise the youngest rocks of the Yukon Coastal Plain and are important economically for their potential reserves of coal and petroleum. They consist predominantly of shale, sandstone and conglomerate; comparatively rare are coal, carbonate and pyroclastic rocks. The Upper Cretaceous sequence consists of the Boundary Creek Formation at the base, followed upward by the Fish River Group (including the Tent Island and Moose Channel Formations), and the overlying Reindeer Formation.

The Boundary Creek Formation is mainly bituminous, marine shale which apparently was deposited during a considerable part of Late Cretaceous time. It is preserved only east of Blow River where it is commonly 500 to 1,000 feet (150-300 m) thick and overlies unconformably Lower Cretaceous strata. This unit is characterized by its brightly coloured sulphate encrustations, bentonite beds and hematite bands, and its deformation into complex, disharmonic folds.

The Fish River Group is a molassoid, terrigenous clastic wedge, approximately 6,000 feet (1,800 m) thick, which is preserved extensively on the coastal plain, in the subsurface of lower Mackenzie Delta and, probably, beneath the continental shelf under Mackenzie Bay.

The Tent Island Formation consists mainly of soft mudstone, approximately 3,000 feet (900 m) thick, immediately west of Mackenzie Delta, and possibly twice as thick farther west in the area of Deep Creek. A basal sandstone and conglomerate unit, here named the Cuesta Creek Member, occurs sporadically at the base of the formation. Microfossil assemblages indicate a Campanian-Maastrichtian age for the formation.

The Moose Channel Formation is subdivided into two members, the basal sandstone member and the Ministicoog Member. The basal sandstone member consists of sandstone, conglomerate, and mudstone strata that are considered to indicate deposition in alluvial, deltaic and littoral environments. The Ministicoog consists of mudstone with minor, intercalated sandstone beds, and is believed to represent tidal-flat to shallow marine environments.

The Reindeer Formation (Aklak Member) is exposed in a few small outcrops west of Mackenzie Delta where it conformably overlies the Moose Channel Formation. A delta-plain facies, consisting of sandstone, conglomerate, mudstone and coal, prevails in these exposures as well as in the I.O.E. Ellice O-14 borehole.

Fossil micro- and macroflora in the Moose Channel Formation indicate a latest Cretaceous (Maastrichtian) age, whereas the micro- and macroflora from the Reindeer Formation indicate an age ranging from latest Cretaceous (Maastrichtian) to earliest Tertiary.

Sandstones of the Fish River Group and Reindeer Formation are composed, mainly, of immature, chert litharenites. The greatest compositional

RÉSUMÉ

Les couches du Crétacé supérieur contiennent les roches les plus récentes de la plaine côtière du Yukon et sont importantes du point de vue économique à cause de leur contenu possible en charbon et en pétrole. Elles sont composées de façon prédominante par du schiste argileux, du grès et du conglomérat; le charbon et les roches carbonatées et pyroclastiques y sont comparativement rares. L'ordre de succession du Crétacé supérieur est le suivant: la formation de Boundary Creek à la base, suivie vers le haut du complexe de Fish River qui comprend les formations de Tent Island et de Moose Channel, et la formation de Reindeer au sommet.

La formation de Boundary Creek est principalement formée de schiste bitumineux constitué d'ancienne argile marine qui semble s'être deposée pendant un laps de temps considerable à la fin du Crétacé. Elle est conservée seulement à l'est de la rivière Blow où elle atteint souvent de 500 à 1,000 pieds d'épaisseur (150 à 300 m) et recouvre en discordance les couches du Crétacé inférieur. Cette unité est caractérisée par ses incrustations de sulfate aux couleurs vives, des lits de bentonite et d'hématite et par sa déformation en plis complexes et dysharmoniques. Le complexe Fish River est un biseau de roches clastiques, molassoïdes et terrigènes d'environ 6,000 pieds (1,800 m) d'épais qui est conservé sur une vaste étendue de la plaine côtière, dans le sous-sol du delta inférieur du Mackenzie et probablement, sous le plateau continental qui se trouve sous la baie Mackenzie.

La formation de Tent Island se compose principalement de pélite tendre. Elle a approximativement 3,000 pieds (900 m) d'épaisseur immediatement à l'ouest du delta du Mackenzie et probablement deux fois cette épaisseur plus loin vers l'ouest dans la region du ruisseau Deep. Une unité de base de grès et de conglomérat, appelée ici le niveau de Cuesta Creek, se retrouve sporadiquement à la base de la formation. Des associations de microfossiles font remonter cette formation au Campanien-Maastrichtien. La formation de Moose Channel est subdivisée en deux niveaux: le niveau de base de grès et le niveau Ministicoog. Le niveau de grès est composé de couches de grès, de conglomérat et de pélite; on considère qu'elles indiquent que la sédimentation a eu lieu dans un environnement alluvial, deltaïque et littoral. Le niveau de Ministicoog est formé de pélite et de petits lits de grès intercalés; il représenterait un vey ou un haut-fond marin.

La formation de Reindeer (niveau d'Aklak) présente quelques petits affleurements à l'ouest du delta du Mackenzie où elle recouvre en concordance la formation de Moose Channel. Le faciès d'une plaine deltaïque, qui consiste en grès, en conglomérat et en pélite domine dans ces affleurements de même que dans le trou de forage I.O.E. Ellice O-14.

La microflore et la macroflore fossiles de la formation de Moose Channel appartiennent à la fin du Crétacé (Maastrichtien), tandis que la microflore et la macroflore de la formation de Reindeer s'étendent de la fin du Crétacé (Maastrichtien) jusqu'au début du Tertiaire.

variations occur in the proportions of chert, plagioclase and volcanic rock fragments; the amounts of plagioclase and volcanic rock fragments are inversely proportional roughly to the amount of chert, and are particularly abundant in the basal sandstone member of the Moose Channel Formation.

Paleocurrents, dispersal trends and the results of a petographic study of clastic particles indicate that, in general, the source of sediment comprising these formations and the heads of drainage systems at that time lay west and south of the present coastal plain. Deltaic sedimentation and the location of depocentres appear to be concentrated in the lower coastal plain and subsurface of the present Mackenzie Delta. Evidence from palynomorph discolouration, coal reflectance, and mineral stabilities indicate that these areas are favourable sites for petroleum generation and entrapment.

Onlapping relationships of the Tent Island Formation on Lower Cretaceous rocks and the less intense deformation of the Fish River Group compared to underlying rocks indicate that tectonism occurred during middle to late Late Cretaceous time in this area.

Les grès du complexe de Fish River et de la formation de Reindeer se composent principalement de spammite pierreuse de silex qui n'est pas complètement formé. Les plus grandes variations de composition se trouvent dans les proportions de silex, de plagioclase et de fragments de roches volcanique; les quantités de plagioclase et de fragments de roche volcanique sont à peu près inversement proportionnelles à la quantité de silex et sont particulièrement importantes au niveau de base de grès de la formation de Moose Channel.

Des paleocourants, des mouvements de dispersion et les résultats d'une étude pétrographique des particules clastiques indiquent, que, de façon générale, l'origine des sédiments qui composent cette formation et les sources du système de drainage de cette époque se trouvaient à l'ouest et au sud de la plaine côtière actuelle. La sédimentation deltaïque et les dépôts principaux semblent concentrés dans la basse plaine côtière et sous la surface du delta actuel du Mackenzie. Des indices fournis par la décoloration palynomorphs, la réflectance du charbon et les stabilités minérales indiquent que ces régions sont des sites très favorable à la formation et l'accumulation du pétrole.

La façon dont la formation de l'île Tent recouvre les roches du Crétacé inférieur et la déformation moins intense du complexe de Fish River par rapport aux roches qu'il recouvre indiquent qu'il y a eu une activité tectonique à partir du milieu jusqu'à la toute fin du Crétacé dans cette région.

UPPER CRETACEOUS STRATIGRAPHY, YUKON COASTAL PLAIN AND NORTHWESTERN MACKENZIE DELTA

INTRODUCTION

Upper Cretaceous strata comprise the youngest rocks of Yukon Coastal Plain and are preserved in synclinal cores and downfaulted blocks such that they form approximately one half of the bedrock surface area. These rocks plunge gently seaward, and are overlain by Tertiary sediments beneath the continental shelf and Mackenzie Delta. The Upper Cretaceous sequence consists of the Boundary Creek Formation at the base, overlain by the Fish River Group (including the Tent Island and Moose Channel Formations), which is, in turn, overlain by the Reindeer Formation. Stratigraphic units comprising this sequence, except for the previously described Moose Channel and Reindeer Formations (Mountjoy, 1967a), are named and defined in this report.

Discussions of sedimentology, paleogeography, paleontology, structural geology, and economic geology are based on detailed bedrock studies undertaken in the eastern coastal plain area (*see* Fig. 1, geological map), reconnaissance geology of the rest of the coastal plain, and studies of samples and logs of several wells, notably the I.O.E. Ellice O-14 borehole located in northwestern Mackenzie Delta.

The strata described here are predominantly terrigenous clastic sedimentary rocks. The small remainder include coal, carbonate rocks, and pyroclastic volcanic rocks. The Boundary Creek Formation is mainly bituminous marine shale, and appears to represent a considerable part of early to middle Late Cretaceous time. The Fish River Group and Reindeer Formation comprise a molasse-like clastic wedge, about 7,000 feet (2100 m) thick, consisting of grey mudstone, siltstone, quartz-chert lithic sandstone, conglomerate, and rare coal seams.

GEOGRAPHICAL SETTING

Upper Cretaceous rocks occur sparsely in the mountainous parts of the north-draining region of northern Yukon Territory. They occur primarily within Yukon Coastal Plain, a strip of land of low relief, about 15 miles wide, between Porcupine Plateau and Beaufort Sea. The coastal plain rises abruptly several hundred feet above the Mackenzie deltaic plain along a straight scarp that trends N 52° W. The tundra-covered land surface gradually increases in elevation toward the southwest, and has the form of a dissected, uplifted pediplain. Outcrops occur primarily in stream banks and gorges, and long rare cuestas where they are weathered and extremely fractured. There are no permanent roads or settlements on the coastal plain west of Mackenzie Delta except for the Distant Early Warning (DEW) establishment at Shingle Point, a few miles northwest of the map-area. In summer, the coastal plain can be reached only by aircraft or boat from the towns of Aklavik and Inuvik, 48 and 70 miles (77 and 114 km), respectively, to the southeast.

In most years geological field work in this area can be started at the beginning of June, although late snowfalls can cause delays lasting until mid-June. The coastal plain is very prone to dense fog and moderate winds, borne off the ice-pack and open leads of the adjacent Beaufort Sea. Base-camps established inland in higher terrain take advantage of warmer air and probably experience less "downtime" due to inclement weather than those set up on the coastal plain.

PREVIOUS WORK

The earliest geological observations of the immediate study-area were made by O'Neill (1915, 1924) during a three-year reconnaissance with the Canadian Arctic Expedition. He traversed the Yukon Coastal Plain several times, where he was impressed by the thick, well-exposed Pleistocene deposits along the Arctic coast.

B.A. Latour (pers. com.) made a brief visit in 1955 to Moose River coal mine at Coal Mine Lake; samples of this coal yielded pollen and spores dated by D.C. McGregor (*in* Mountjoy, 1967a, p. 9) as upper half of the Upper Cretaceous. During Operation Porcupine of the Geological Survey in 1962, Mountjoy made observations of the Upper Cretaceous rocks on and near Big Fish River. In his subsequent report on these rocks, Mountjoy (1967a) discussed the Moose Channel Formation. D.K. Norris (1970, 1972a, 1974) made follow-up field studies to Operation Porcupine, and reported briefly on thicknesses and some of the sedimentological properties of the Fish River Group.

During the last two decades, several geological reconnaissance missions were sent into this area by petroleum companies, but the results of this work have not yet been published. A Master of Science thesis by Holmes (1972) on the Moose Channel Formation was based on data and samples gathered while working for the Atlantic Richfield Company. A concise version of this report (Holmes

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Manuscript received: January 2, 1974

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and Oliver, 1973) was presented to the Canadian Arctic Geology Symposium in Saskatoon.

Chamney (1971, 1973a) established 7 physical stratigraphic divisions and 23 biostratigraphic divisions based on microfossil recovery from cuttings and cores of the Reindeer D-27 borehole, the first well drilled on Mackenzie Delta. An attempt is made in this report to correlate his informal divisions to units recognized in the Ellice O-14 borehole, located 30 miles (49 km) to the west, and to the surface stratigraphy discussed here.

PRESENT STUDY

With the advent of active exploration for oil and gas in the Mackenzie Delta area in the late 1960's, the need for more surface and subsurface stratigraphic control in the coastal plain and northern Richardson Mountains regions was immediately realized. Very little information had been published on rocks younger than the Aptian Upper sandstone division of Jeletzky (1958, 1960), and the writer's present project was designed to fill these knowledge gaps.

The present study began in the summer of 1970 when the writer shared a camp and helicopter, supplied by Liftair International Limited, with D.K. Norris and J.A. Jeletzky of the Geological Survey. Stratigraphic information on the Fish River Group was obtained during the coarse of a two-week traverse by inflatable boat down Little Fish (Cache) Creek and Big Fish River (Young, 1971). This method of travel allowed the writer plenty of time to visit nearly all outcrops along the riverbanks, except when running the rapids in Fish River canyon near the confluence of Little Fish (Cache) Creek.

In June and July of 1971, a base camp was maintained at Coal Mine Lake near the centre of the map-area (Fig. 1). From this camp, using a helicopter chartered from Shirley Helicopters Limited and assisted by D.H. McNeil, nearly all stream cuts and ridge outcrops in the map-area were examined (Young, 1972). Foot traverses were made along Boundary, Eagle, Hornet, Aklak, and other unnamed creeks, starting from their first headward outcrops.

During the field seasons of 1970, 1971 and 1972, reconnaissance stops, foot traverses, and measured sections in Upper Cretaceous rocks were described at various locations on the coastal plain (Fig. 2). Drill cuttings and cores from the entire I.O.E. Ellice O-14 borehole, and the upper half of the I.O.E. Blow River YT E-47 borehole were examined and logged in detail by the writer.

ACKNOWLEDGMENTS

The writer wishes to thank D.K. Norris, J.A. Jeletzky, C.J. Yorath, D.F. Stott, and T.P. Chamney, all officers of the Geological Survey of Canada, for their advice during the initial stages of this project and for many useful discussions.

Discussions on outcrop occurrences, stratigraphy, and sedimentological problems with D.W. Holmes, formerly of Atlantic Richfield Canada Limited, were most useful and stimulating. The field assistance offered by D. Loney in 1970 and by D.H. McNeil, Z. Hadnagy, D. Gardner, and J. Irish is gratefully acknowledged.

Foraminiferal identifications were made by T.P. Chamney, and palynological determinations by W.W. Brideaux, both of the Geological Survey. Plant remains were identified by C.J. Smiley of the University of Idaho. Clay mineral analyses were made by A.E. Foscolos of the Geological Survey. C.J. Yorath kindly donated his sample-description log of the Reindeer D-27 borehole for incorporation in this report.

The helpful comments of A.W. Norris, D.K. Norris, and J.A. Jeletzky, who critically read this manuscript, are gratefully acknowledged. Other suggestions for improvement of the text were kindly provided by R.W. Macqueen, D.W. Myhr, and numerous other geologists familiar with the geology of this area.

GEOGRAPHICAL NAMES

With the recent increased interest in the economic potential of Mackenzie Delta and surrounding area, the need for more geographical names is evident. Also, vague references to various unnamed streams along which important geological outcrops occur are undesirable. Accordingly, several names were submitted to, and approved by, the Canadian Permanent Committee on Geographic Names (*see* Fig. 1).

The names important to the report include the following:

Eagle Creek - a northward-flowing stream whose course lies just west of the Yukon-Northwest Territories boundary and which drains into newly named Scow Lake in northwestern Mackenzie Delta.

Hornet Creek - a major southwestern tributary of Eagle Creek, which it joins at Latitude 68° 44'20"N, Longitude 136°35'00"W.

Aklak Creek - the largest stream debouching into Coal Mine Lake of northwestern Mackenzie Delta. This is the name used by the local Indians for this creek and means "bear" in the Loucheux language.

Boundary Creek - a major western tributary of Big Fish River, whose junction with the latter almost coincides with the point where Big Fish River crosses the Yukon-Northwest Territories boundary at Latitude 68°30'15"N.

Cuesta Creek - a northward-flowing tributary of Rapid Creek, which it meets at Latitude 68° 45'00"N, Longitude 136°53'30"W, and which cuts through a prominent, north-south trending, unnamed cuesta.

A ruling was obtained from the Committee regarding the present ambiguity in the names for the major river flowing into northwestern Mackenzie

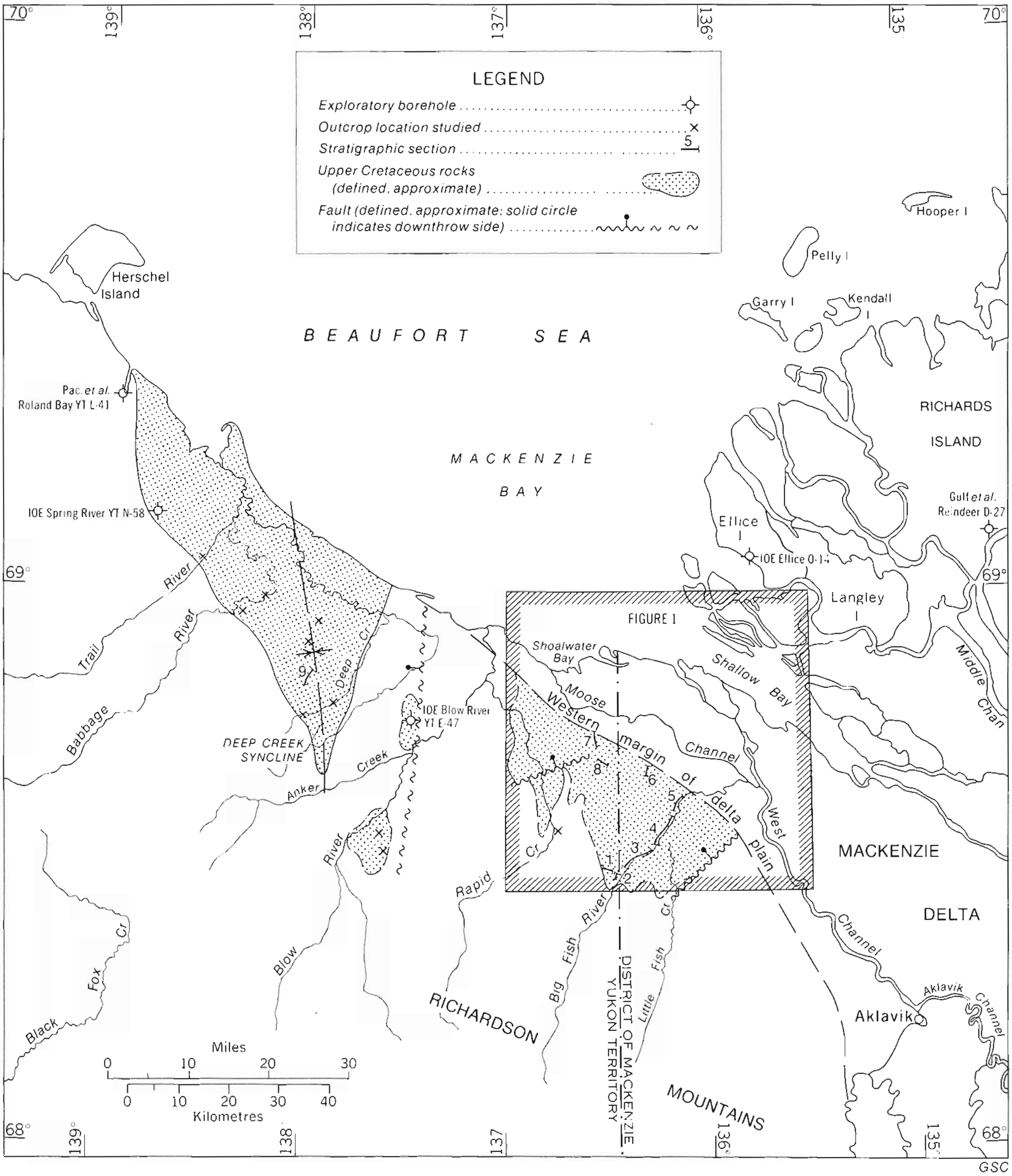

Figure 2. Location map with simplified geological outline

Delta. Big Fish River is the correct official name, and not Fish River as printed on the Blow River, 117A map-sheet, Edition 1, published by the Surveys and Mapping Branch. Also, the large tributary of Big Fish River labelled Cache Creek on the same map-edition should be called Little Fish Creek. To avoid confusion in the report, the latter is referred to as Little Fish (Cache) Creek.

GEOLOGICAL SETTING

The geological history of northern Yukon Territory since Precambrian time is relatively complex, consisting of numerous periods of sedimentation of various styles, punctuated by tectonic activity and a few major orogenic episodes. General reviews of this history have been published by Martin (1959), Jeletzky (1961, 1962), Norris *et al.* (1963), Douglas (1970, p. 461), Norris (1973), Miall (1973), and Lerand (1973).

Mountain building occurred in the Racklan Orogeny (Gabrielse, 1967) during the late Precambrian Era, and was followed by a long period of sedimentation resulting in the Neruokpuk Formation of northern Yukon. In Late Devonian and Early Mississippian times, these rocks were compressed and deformed during the Ellesmerian Orogeny. Areas uplifted by this diastrophism include British Mountains, Aklavik Arch and Richardson Mountains. Further depositional intervals interrupted by periods of uplift are recorded during the Mississippian, Pennsylvanian, Permian, and Triassic Periods.

In Early Jurassic time, a seaway inundated northern Yukon and resulted in deposition of a thick, black shale deposit (Kingak Formation) extending from Eagle Plain through the coastal plain into Alaska. Quartz sand was deposited mainly on the southeastern margin of this seaway and, in Early Cretaceous time, several northwest-projecting sandstone tongues developed. This sequence has been well documented by Jeletzky (1958, 1960, 1961, 1971b) in areas south of the coastal plain.

In the late Early Cretaceous (Aptian), the Upper sandstone division (Jeletzky, 1958) marks a major tectonic episode because its sandstone is richer in chert and limestone fragments than earlier deposits. It grades upward and laterally into a very thick, shaly, flyschoid succession which was deposited in a north-trending trough running through Blow River valley (Jeletzky, 1971b; Young, 1974). The flyschoid sequence rapidly thins toward the east in the region of Big Fish River, where phosphatic iron carbonate rock and shale accumulated on a restricted shelf. In Late Albian and possibly earliest Late Cretaceous time, subsidence of this trough gradually ceased, and its sediments were subjected to tectonic stresses and, in part, raised above sea level. Following a brief period of emergence, the Late Cretaceous depositional intervals were initiated, and the resulting sediments are described in this report.

STRATIGRAPHY

The Upper Cretaceous sequence of the Yukon Coastal Plain includes, in ascending order, the Boundary Creek, Tent Island, Moose Channel and Reindeer Formations. The Tent Island and Moose Channel Formations comprise the Fish River Group. The ages, thickness ranges, and gross lithologic aspects are summarized in the Table of Formations. Except for the Moose Channel and Reindeer Formations, all stratigraphic names shown in Table 1 are new.

SERIES	STAGE		Formation and thickness	Lithology
?TERTIARY	?PALEOCENE		*REINDEER* (1900± ft) (579± m)	*Nonmarine sandstone, coal, siltstone, conglomerate (Aklak Member)*
UPPER CRETACEOUS		Conformable contact		
	MAASTRICHTIAN	*Fish River Group*	*MOOSE CHANNEL* (2000-3000 ft) (610-914 m)	*Silty mudstone (Ministicoog Member); sandstone, in part pebbly, coarse-grained, minor shale, conglomerate, coal*
	CAMPANIAN		*TENT ISLAND* (2400-5000± ft) (732-1524± m)	*Mudstone, light grey to bluish grey, in part silty, sandy, or pebbly; conglomerate and sandstone at base (Cuesta Creek Member)*
		Disconformity		
	CAMPANIAN-(?)CENOMANIAN		*BOUNDARY CREEK* (0-3600+ ft) (0-1097+ m)	*Shale, dark grey, bituminous, soft, yellow to red weathering, bentonite, rare limestone and siltstone*
?Angular unconformity				
LOWER CRETACEOUS	ALBIAN		*Unnamed shale, phosphatic ironstone*	

GSC

Table 1. Table of formations (Yukon Coastal Plain)

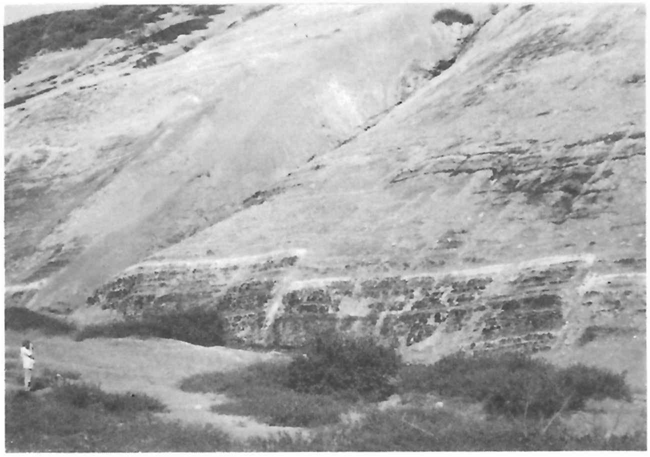

Figure 3. Boundary Creek Formation at type section on Boundary Creek. GSC 199048

The Boundary Creek Formation is preserved, between two unconformities, only in the eastern coastal plain near Mackenzie Delta, and is a structurally incompetent shale unit containing bentonite and limestone beds. The Fish River Group commences with the Tent Island Formation, a thick, recessive, grey mudstone unit with minor sandstone bands and beds. At its base is a locally occurring sandstone and conglomerate here called the Cuesta Creek Member. Owing to the imprecise definition of the Moose Channel Formation (Mountjoy, 1967a), this name has been applied by some workers (Holmes and Oliver, 1973) to the entire Fish River Group. However, the original intent (E. Mountjoy and D.K. Norris, pers. com.) and usage in the Geological Survey and elsewhere restricts the Moose Channel to the upper sandstone formation only, a practice followed here. At the type section on Big Fish River, the Moose Channel Formation consists of a sandstone member, 1,900 feet (580 m) thick, overlain by a poorly exposed mudstone unit, 975 feet (300 m) thick, here called the Ministicoog Member. The conglomeratic and coal-bearing Aklak Member also was included originally in the Moose Channel Formation (Mountjoy, 1967a; Young, 1972), but is now included in the Reindeer Formation as a result of regional subsurface correlations.

The organization of the descriptions of the stratigraphy and sedimentology is as follows: the Boundary Creek Formation is discussed completely in the usual format in this chapter; accounts of units in the Fish River Group and the Reindeer Formation, with abridged lithologic descriptions, also are found in this chapter. Detailed sedimentological descriptions and interpretations of the Fish River Group and Reindeer Formation are reserved for a separate chapter, as is a general and comparative description of sandstone petrography. The problems of correlating stratigraphic sections within the study-area, as well as interregionally, also are discussed in a separate chapter.

Boundary Creek Formation

Name and distribution

The name Boundary Creek Formation is proposed for a distinctive Upper Cretaceous shale unit outcropping in eastern Yukon Coastal Plain. It is well exposed in the high northern bank of the lower course of Boundary Creek after which the formation is named. The composite section available at this site is designated the type section.

The Boundary Creek Formation is not extensively preserved. Also, because of its soft, recessive nature, the formation outcrops only in active, stream-cut gullies and gorges. Its main outcrop area lies in the environs of Big Fish River, Little Fish (Cache) Creek, and lower Rapid Creek (Fig. 1). It was not recognized in outcrops west of Blow River, but possibly occurs in the depth-interval 3,370 to 3,990 feet (1030-1220 m) in the I.O.E. Blow River YT E-47 borehole. The Upper Cretaceous Shale division described by Jeletzky (1960) is believed to be a limited occurrence of the Boundary Creek Formation in eastern Aklavik Range. This is substantiated by the great similarity in lithology at each location, by the similarity in paleontological age assignments (*see* below), and by the occurrences of fish and bird bone beds both at Treeless Creek and in the Bituminous Shale Zone of Anderson Plain (Chamney, 1973a), which is correlated with the Boundary Creek Formation.

The Boundary Creek Formation is approximately 800 feet (240 m) thick at its type section, 540 feet (165 m) thick a few miles to the south on Big Fish River, and at least 750 feet (230 m) thick on Little Fish (Cache) Creek (Lat. 68°28'N; Long. 136° 12'W). Because the formation is readily deformed tectonically and has a tendency to slump in outcrops, these thicknesses are only approximations. The supposed equivalent strata in the Blow River E-47 borehole are about 600 feet (180 m) thick, taking into account bedding dips. The Treeless Creek section in eastern Aklavik Range was estimated by Jeletzky (1960) to be 900 to 1,000 feet (275-305 m) thick. A section with unexposed basal contact measured near Cuesta Creek, a tributary of lower Rapid Creek, is approximately 3,600 feet (1100 m) thick. A few faults observed within the section may cause stratigraphic repetitions but probably are not responsible for all of this increased thickness. Seven miles (11 km) to the east on Hornet Creek, the formation wedges out completely below the Fish River Group.

Lithology

The Boundary Creek Formation is reasonably constant in lithologic character throughout its thickness, and cannot be subdivided into mappable members. The formation consists mainly of dark grey to black, soft shale, which is oxidized to various colours including yellow, red, and mahogany brown, but predominantly light to medium grey (Fig. 3). Thin beds and bands of yellow-weathering, putty-like, greyish white bentonite occur throughout the unit, and are concentrated in certain zones. High in the section, bentonitic seams attain thicknesses of about one foot (0.3 m).

Thin carbonate beds and lentils comprise a minor part of the lower half of the formation, and include argillaceous or sandy limestone in the type section, bedded sideritic ironstone on Big Fish River and Rapid Creek, and argillaceous dolostone in the Cuesta Creek section. Calcareous and sideritic concretions are common in the medial third of the formation, and large septarian nodules, up to five feet (1.5 m) wide, are found about 200 feet (61 m) below the top at the type section. Similar nodules observed at the Treeless Creek section contain veins of amorphous- and resinous-appearing calcite.

Arenaceous terrigenous clastics are notably rare in the Boundary Creek Formation. Thin-bedded siltstone is present in small amounts in all studied localities, but only at Little Fish (Cache) Creek were sandy siltstone beds observed, and these displayed flute-casts and groove-casts.

An outstanding feature of this formation is the colourful weathering encrustations formed largely of sulphate minerals and iron oxides. Gypsum (selenite) and jarosite are common weathering products of the shales, and barite was observed rarely as veins. Some of these minerals may have resulted from spontaneous combustion of pyritic, bituminous shales, such as that occurring in the "bocannes" of the correlative "Bituminous Shale Zone" on Anderson Plain (Yorath *et al.*, 1969). The more common ochrous and selenitic encrustations, however, formed particularly on slightly calcareous, hard mudstone beds, seem more likely to be products of leaching and hydration in a semi-arid to arid climate.

A preliminary analysis of the clay mineralogy of these shales was made by A.E. Foscolos at the Institute of Sedimentary and Petroleum Geology, and the semi-quantitative results of X-ray diffraction patterns are given in Table 2. The montmorillonite present in two samples taken from a yellow-banded shale unit verifies the presence of bentonite, and suggests a volcanic source for some of the clay. Other evidence of volcanic activity during deposition of the muds includes the presence of small andesitic lapilli in digested micropaleontological samples from beds associated with concretions of bentonite seams (T.P. Chamney, pers. com.).

SAMPLE	Dolomite	Siderite	Pyrite	Quartz	Feldspar	Kaolinite	Illite	Chlorite	Montmorillonite	Gypsum
19 YAb-17			10	59	9		12	10		
19 YAb-20		4	8	55	7		15	11		
19 YAb-6	11			46	9		6	4		24
20 YAb-1				70	13			3	10	4
20 YAb-4	3			65	14		2	3	13	
20 YAb-7				68	13		16	3		
57 YA-2*	3			59	14		14	10		
AVERAGE	2.5	0.5	2.5	60	11		9	6	3	4

* Sample from Cuesta Creek section; other samples from type section

GSC

Table 2. Composition of shale samples, Boundary Creek Formation

The presence of limestone beds in this formation is unique among the Mesozoic formations of this region. The study of a thin section of one of these beds indicates that the rock is a fairly pure calcarenite composed of monocrystalline plates and fragments, suggesting echinodermal debris. Some limestone samples contain quartz sand grains of similar size (ca. 0.20 mm diam.) as the carbonate particles. Other calcareous beds apparently consist entirely of fine spicular fragments.

Structural relationships

The Boundary Creek Formation is one of the most structurally incompetent Mesozoic units in the coastal plain area as indicated by its deformation into disharmonic folds. Its relative plasticity contrasts with the relatively brittle nature of subjacent and overlying units, which commonly are faulted where they are associated with folded Boundary Creek strata. This characteristic is well exemplified on Little Fish (Cache) Creek where brittle Albian shale and turbidites are deformed into variously dipping, fault-bounded slices, whereas the overlying Boundary Creek shale is disharmonically folded. In the overlying Tent Island Formation, faults occur again without associated folding. Similar structural relations were noted along the lower course of Rapid Creek. The possibility of this plastic shale contributing to shale diapirs in the offshore subsurface therefore deserves serious consideration.

The lower contact of the Boundary Creek Formation was observed in the banks of Big Fish River and Rapid Creek, where a basal, red-weathering shale unit lies conformably but with sharp contact on bedded ironstone and shale of Albian age. Ferruginous beds resembling the Albian ironstone occur within the basal red-weathering shale, and as a continuous, transitional facies between the Albian (Lower Cretaceous) strata and Upper Cretaceous shales. This contact, however, probably is unconformable in the Big Fish River area, because a considerable thickness of Albian turbiditic sandstone and shale occurs between the bedded ironstone and Boundary Creek Formation on nearby Little Fish (Cache) Creek.

In the Blow River E-47 borehole, the dipmeter log indicates a large angular discordance at a depth of 3,990 feet (1220 m). Overlying beds, thought to represent the Boundary Creek Formation, dip about 20 degrees to the southeast, but the underlying Albian shales dip 20 to 30 degrees northwestward. This contact can be interpreted alternatively as a fault surface.

The upper contact rarely is exposed, but from mapping patterns is inferred to be unconformable locally. On Hornet Creek, the basal conglomerate of the Fish River Group rests with slight angular discordance on brittle, hard shale of probable Albian age. On Boundary Creek and Big Fish River, however, the basal beds (Cuesta Creek Member of Fish River Group) consist of platy siltstone and shale which overlie, apparently concordantly and possibly conformably, the non-arenaceous Boundary Creek shale.

Depositional environment

No detailed sedimentological analysis of the Boundary Creek Formation was undertaken, but data pertaining to its environment of deposition can be inferred simply from gross lithology and biotic characteristics. The vertical homogeneity of the bituminous, pyritic mudstone, which represents a long span of Late Cretaceous time (*see* below), indicates that there was a fairly continuous, slow deposition of clay-size particles onto a quiet, practically stagnant basin floor. This basin contained marine waters as evidenced by such marine life-forms as echinoderms, ammonites, radiolarians, and foraminifers.

The abundance of bitumen and the presence of pyrite in the shale attest to anaerobic, reducing conditions which were long maintained on the seafloor. Although it was suggested previously (Young, 1974) that this formation represented hypersaline conditions on the basis of the contained sulphate minerals, it is now believed that the latter are products of late diagenesis and weathering, and do not reflect salinity of the original seawater.

The lack of arenaceous influxes and the vertical continuity of the euxinic shale facies reflect the stability of the basin in this area. The numerous occurrences of bentonite layers in the section, however, attest to volcanicity and, therefore, instability within the region. This deposit represents a metastable tectonic period established between an earlier flyschoid phase in the late Early Cretaceous, and a later molassoid phase (Young, 1974), represented by the Fish River Group.

Age

Outcrops of the Boundary Creek Formation on Treeless Creek (Upper Cretaceous Shale division) contain pelecypods and ammonites that indicate that the beds there are of Cenomanian to Turonian age (Jeletzky, 1960, p. 22). No macrofossils or indigenous microflora have been recovered from the formation in the Big Fish River area, and microfossils are relatively sparse. Those that have been recovered are confined largely to the upper half of the formation, and consist of vertebrate fragments, radiolarians and foraminifers similar to those of the Bituminous Shale Zone (Chamney, 1972; pers. com.). The Bituminous Shale Zone has an upper age limit of early Campanian on the basis of vertebrate fossils (Russell, 1967) and pelecypods (Jeletzky, 1971a).

The three members of the formation at the Treeless Creek section can be correlated with similar units at the Boundary Creek and Big Fish River sections on lithologic similarity. The "orange-weathering member" and the underlying "dark grey shale member" both lie stratigraphically below the section sampled and studied by Chamney (1972) and, therefore, permit a tentative Cenomanian-Turonian age assignment for the lowest part of the formation.

Thus, the Boundary Creek Formation seems to represent fairly constant sedimentary conditions throughout the longer part of Late Cretaceous time, including Cenomanian to early Campanian Stages. Much more paleontological work is required to refine this range in age and to determine whether or not hiatuses may in fact be represented within the formation.

FISH RIVER GROUP

The Fish River Group derives its name from Big Fish River (referred to simply as "Fish River" by virtually everyone conversant with the area, e.g. Holmes and Oliver, 1973) along whose banks the group is exposed almost entirely. The type section of the group is designated as the composite section of gently northeast-dipping strata exposed for a distance of 14 miles (23 km) along the river, despite the presence of minor faults and the poor exposure of mudstone units. The total thickness of the section on Big Fish River is approximately 6,000 feet (1830 m), as determined from direct field measurements and graphic calculations over covered intervals. The entire Fish River Group is represented also along the course of Eagle Creek, although one major and several minor faults disrupt the stratigraphic continuity along the stream's course. By summing the measured stratigraphic thicknesses and restoring the formations to their proper sequence, the total thickness of the group there also is approximately 6,000 feet (1830 m).

The Fish River Group occurs in the Blow River valley within a probable downfaulted block, and is poorly exposed immediately south of the mouth of Fitton Creek (Fig. 2). At this location, it is dominantly mudstone (Tent Island Formation probably) but also includes two, widely separated, ridge-forming sandy units, each displaying nonmarine characteristics. The upper unit is 380 feet (116 m) thick and probably represents the Moose Channel Formation. The lower unit of sandstone and mudstone, 750 feet (230 m) thick, occurs approximately 1,500 feet (460 m) stratigraphically below the upper; it is possibly equivalent to the Cuesta Creek Member of the Tent Island Formation. Downstream from this outcrop-area in the I.O.E. Blow River YT E-47 borehole, the uppermost 4,000 feet (1220 m) of section were identified with the aid of foraminifers (T.P. Chamney, pers. com.) as the Fish River Group.

West of Blow River, the Fish River Group again outcrops in the core of Deep Creek Syncline (Fig. 2, Sec. 9), where it is poorly exposed. The thickness of the Tent Island Formation is not well established, although it appears to be considerably thicker here [10,000 feet (3000 m) according to Norris, 1972a, p. 97] than it is farther to the east. The arenaceous upper part, which may include the basal part of the Reindeer Formation, is approximately 3,000 feet (920 m) thick.

Tent Island Formation

The dominantly pelitic unit referred to previously as the "Upper Cretaceous unnamed shale unit" (Young, 1971; Chamney, 1972), "Units 1 and 2" (Young,

Figure 4. Gorge of Big Fish River viewed downstream from confluence with Boundary Creek; Tent Island Formation exposed in canyon walls. GSC 199054

1974; Holmes and Oliver, 1973), and erroneously as the "Upper Cretaceous shale division" (Young, 1972), is named here Tent Island Formation. The name refers to Tent Island in Shoalwater Bay, and the name of the map-area (NTS 117A/16) in which most of the studied outcrops of the formation are located. The type section (Secs. 2 and 3, Appendix) is incompletely exposed on the northwest bank of Big Fish River from its confluence with Boundary Creek at the Northwest Territories-Yukon boundary (Fig. 4) to its junction with Little Fish (Cache) Creek. Most of the upper half of the formation consists of soft clay-shale, thus fresh outcrops are rare. On Big Fish River, this part of the formation forms a long, high bank characterized by slumped, bluish grey mud.

Occurring discontinuously at the base of the formation is a resistant sandstone and conglomerate unit with included mudstone beds. This unit is named here the Cuesta Creek Member after the creek which cuts through a prominent cuesta formed by resistant strata of this unit west of lower Rapid Creek. Previously, it was referred to as the "basal chert conglomerate and sandstone division" (Young, 1972). Except for the lower contact, the member is exposed almost completely on Big Fish River where it crosses the Yukon-Northwest Territories boundary, and this location is selected as the type section (Sec. 2; Fig. 4).

The thicker, dominantly pelitic part of the Tent Island Formation, lying above the Cuesta Creek Member, is named informally the mudstone member.

In a previously published stratigraphic section of Little Fish (Cache) Creek, Young (1971) reported the Tent Island Formation to be 1,100 feet (335 m) thick. At this locality, however, the unit is truncated at its base by a fault, and its true thickness is not represented. At its type section the Tent Island Formation is about 3,125 feet (950 m) thick, and on Eagle Creek its thickness is about 2,800 feet (850 m). Chamney (1972) expressed the opinion that, in the Reindeer D-27 borehole, the formation is represented by the depth-interval 6,960 to 10,720 feet (2121-3267 m), a thickness of 3,760 feet (1146 m).

West of Mackenzie Delta, the Tent Island Formation has been recognized in scattered outcrops along the lower coastal plain between West Channel and Rapid Creek. The formation apparently thickens toward lower Rapid Creek, although the basal Cuesta Creek Member shales out in the same direction. These trends and the possible northwestward disappearance of the unconformity separating the Fish River Group from the underlying shale sequence may result in the replacement of the Tent Island Formation by a much thicker shale sequence encompassing the older Boundary Creek Formation.

In the Big Fish River area, the Cuesta Creek Member rests unconformably on the Boundary Creek Formation. At the type section, the unconformity is not exposed, but is believed to underlie a succession, 100 feet (30 m) thick, of graded sandstone and interbedded mudstone beds assigned to the Cuesta Creek Member (Sec. 2, Appendix). This succession, in turn, is scoured and its upper beds truncated by conglomerate and coarse sandstone beds, conditions that suggest an unconformable contact. The writer, however, considers that these coarse strata are more likely to represent channel-scouring of pro-deltaic and delta-front beds by the seaward advance of a delta distributary because, laterally, the lower succession is preserved and grades vertically into a sandstone unit.

Elsewhere, as on lower Rapid Creek, the conglomerate rests directly on eroded mudstone of the Boundary Creek Formation (Fig. 5). At this locality, the amount of angular discordance is one foot in 25 (2.5°), with progressive downcutting northward. Four miles (6.4 km) to the northwest, however, where the continuation of the cuesta-forming outcrop belt meets the south bank of Rapid Creek, the Cuesta Creek Member is a mere 15 feet (4.5 m) thick, and barely recognizable. There, it is replaced almost entirely by sandy mudstone and shale, and no sharp contact with the underlying Boundary Creek Formation is discernible. Thus, the unconformity may be

Figure 5. Cuesta Creek conglomerate resting unconformably on Boundary Creek shale, lower Rapid Creek. GSC 199066

Figure 6. Cuesta Creek Member at type section, Big Fish River. GSC 199061

Figure 7. Pebbly mudstone facies of Tent Island Formation; Little Fish (Cache) Creek. GSC 202502

replaced northward by a continuous sedimentary sequence in conjunction with the disappearance of the Cuesta Creek Member.

The upper contact of the Tent Island Formation with the Moose Channel Formation is selected at the base of the relatively continuous succession of coarse clastic sediments of that formation, and is generally distinct (*see* discussion under heading Sedimentology of Fish River Group and Reindeer Formation, and Fig. 16).

Cuesta Creek Member

At its type section, the Cuesta Creek Member is 325 feet (100 m) thick plus an unknown part of a covered interval, 20 feet (6 m) thick, at the base (Sec. 2); at Eagle Creek it is 355 feet (108 m) thick. It is present as isolated outcrops in the valley of lower Rapid Creek, but the only complete exposure in this area is on the prominent cuesta, where it is 280 feet (85 m) thick. The member has not been recognized southeast of Big Fish River, and seems to be absent in the Reindeer D-27 borehole. The member also is present locally in the Deep Creek area where it may be confused with the Moose Channel Formation. A section measured on Deep Creek at Latitute 68°47'N, Longitude 138°01'W is faulted, but approximately 450 feet (137 m) of interbedded conglomerate, sandstone and mudstone are indicated. There, the member forms a low ridge trending northwest, directly east of Hidden Lake. Farther northwest, good exposures of the Cuesta Creek Member are present in the banks of Trail River (Lat. 69°02'N, Long. 138°34'W), where it is about 150 feet (46 m) thick (Norris, 1974).

The upper contact of the Cuesta Creek Member is sharp at some places but gradational at others. It is chosen at the top of the highest, relatively resistant sandstone or conglomerate bed of the Cuesta Creek Member. Pebbly mudstone commonly found above the resistant sandstone is included with the mudstone member of the Tent Island Formation.

At the type section, the member consists of four units (Fig. 6) which, in ascending order, include: (i) a basal sandstone and shale unit, (ii) a lower sandstone and conglomerate unit, (iii) a mudstone unit, and (iv) an upper sandstone and conglomerate unit. Only the upper three units are exposed at the prominent cuesta west of Rapid Creek.

The coarse clastic units commonly weather to a characteristic deep red-orange colour. Fresh surfaces are mainly medium to dark grey due to the high content of dark chert and slate fragments. The largest phenoclast was observed at Hornet Creek and measured 3 feet by 2 feet (90 x 60 cm) in two visible dimensions. The abundant conglomerate at the type section displays clasts as much as one foot (0.3 m) in maximum dimension. At Eagle Creek, conglomerate is rare, and the member there is mainly sandstone and friable argillaceous sand, with minor coal laminae and seams.

The mudstone unit consists of silty, dark grey-brown brittle shale which is, in part, sandy and carbonaceous and locally contains dark brown limy beds and concretions.

Mudstone member

The rocks of the mudstone member of the Tent Island Formation generally are soft, easily eroded, and exhibit a muddy aspect in the field, especially near Big Fish River and eastward. Toward Rapid Creek, the mudstone becomes harder and darker grey, and gradually loses its muddy appearance on weathered banks. The member causes high-density drainage patterns to develop wherever it is nearly flat-lying.

Near the base of the member, pebbly mudstone units are common, and are in part graded and interbedded with stratified non-pebbly mudstone (Fig. 7). Interbedded sandstone and siltstone beds also are common in the basal half. On Eagle Creek and Big Fish River, sandstone is practically absent; however, thin-bedded, laminated and cross-laminated calcareous siltstone is common. Cone-in-cone structure is commonly developed on the undersides of siltstone and rare argillaceous limestone beds, both in the Big

Fish River and Deep Creek areas. This structure apparently is a characteristic of the member in this region.

The upper half of the member is very recessive, and consists mainly of medium grey mudstone and shale. In places, the mudstone contains nodular to lenticular pods of silt, sand and, rarely, gravel. A few interbeds are enriched in sandstone, sand, silt, and pebble-conglomerate interbeds. Such interbeds are normally very thin and exhibit bright yellow, orange, and olive-green weathering colours. Carbonaceous particles are abundant in these coarser intervals.

X-ray analyses of "clay" mineralogy for five mudstone samples, two from Little Fish (Cache) Creek and three from Eagle Creek, revealed illite and chlorite as the only clay minerals, and quartz as the major clay-size component (A.E. Foscolos, internal report). The average composition of the five samples is:

Quartz	43.0%
Feldspar	10.8%
Illite	22.8%
Chlorite	21.6%
Carbonate	1.8%

Microscopic examination of several sandstone and siltstone samples revealed the universal presence of calcite cement and a constant particulate composition dominated by quartz, chert, and metasedimentary rock fragments. Minor components include potash feldspar, plagioclase, andesitic rock fragments, carbonaceous flakes and shards, and mica. All samples are well compacted and non-porous. Sand grains are mainly angular to subangular, very fine grained to fine grained, and moderately to well sorted. Incipient replacement of feldspar and labile grains by calcite has occurred in samples where the latter mineral is abundant.

Paleontology and age

In its type area, the Tent Island overlies disconformably the Boundary Creek Formation, which is biostratigraphically equivalent to the Bituminous Shale Zone of Anderson Plain (Chamney, 1972). Although no macrofossils were recovered from the basal Cuesta Creek Member, palynological samples from this unit at Eagle Creek yielded poorly preserved indigenous palynomorphs (GSC loc. C-11376) identified by W.W. Brideaux of the Geological Survey as:

Cicatricosisporites sp.
Inaperturopollenites hiatus (Potonié) Thomson and Pflug
Aquilapollenites sp.
fragment plant debris

Brideaux considered this assembalge to be probably Campanian or Maastrichtian in age. Hence, in the eastern outcrop area, the basal Tent Island Formation appears to be no older than Campanian in age.

Higher in the same section, but still within the basal half of the formation, the following palynomorphs were identified by Brideaux (GSC locs. C-11380 and C-11399):

Triatriopollenites sp.
Triporopollenites sp. cf. *T. rugatus* Newman
Betulaceoipollenites sp. cf. *B. infrequens* (Stanley) Norton and Hall
Inaperturopollenites hiatus (Potonié) Thomson and Pflug
Stereisporites antiquasporites (Wilson and Webster) Dettmann
Cleistosphaeridium sp.
Aquilapollenites sp. A
unidentifiable bisaccates

This assembalge was dated as Late Cretaceous, probably Maastrichtian in age.

No macrofossils or diagnostic microfossils have been recovered to date from the type section on Big Fish River but, on nearby Little Fish (Cache) Creek, five miles (8 km) east, the formation has yielded abundant foraminifers, dinoflagellates, pollen and spores, and the only macrofossil from the entire Fish River Group. This was identified by J.A. Jeletzky as a pelecypod, possibly of the genus *Acila*.

A rich microfauna together with a mixed indigenous and recycled microflora were recovered from an interval, 200 feet (61 m) thick, whose base lies about 900 feet (275 m) below the Moose Channel Formation. T.P. Chamney of the Geological Survey examined the microfauna and reported the following species (GSC locs. C-6059 to C-6067) of foraminifers:

Cyclammina sp. 1A
Trochamminoides sp. 9B
Haplophragmoides sp. 66
H. var. sp. 87
H. ex. gr. *H. gigas minor* Nauss
?Gaudryina sp.
Verneuilinoides fischeri Tappan
Saccammina sp.
Marsonella (Dorothia) sp. 13B
Ammodiscus cf. *A. planus* Loeblich
Trochammina sp. G 132
T. sp. G 138
?Arenobulimina sp. 8
A. ex. gr. *A. paynei* Tappan
Bathysiphon sp. 13
Hippocrepina (Hyperammonoides) sp. 22
?Globorotalia sp.
Reophax sp.
Praebulimina venusae Nauss
Gyroidina (Serovaina) sp.

The same samples yielded the following palynomorphs, identified by W.W. Brideaux:

Deflandrea spectabilis Alberti
D. magnifica Stanley
Astrocysta cretacea Pocock ex Davey
Hystrichosphaeridium? sp.
recycled Paleozoic, Triassic and Early Cretaceous miospores, probable Maastrichtian dinoflagellates

According to Chamney, the foraminifers comprise the *Cyclammina* sp. 1A Zone assemblage which he reported in the Reindeer D-27 borehole (Chamney, 1971) in the depth-interval 9,200 to 9,560 feet (2800-2920 m). This assemblage is biostratigraphically equivalent to the Schrader Bluff Formation of northern Alaska, and now is considered to be Maastrichtian in age (Chamney, 1973b). Brideaux noted that the presence of *Deflandrea magnifica* Stanley, if indigenous, "can mean only that the sample is no older than Maastrichtian or no younger than Early Paleocene". Hence, the upper half of the Tent Island Formation in the Big Fish River area is reasonably well dated as Maastrichtian in age.

Far to the northwest on Trail River, an arenaceous section, 150 feet (45 m) thick, containing coaly shale lentils was described and interpreted to be basal Moose Channel Formation by D.K. Norris (1974, p. 348, 349). Brideaux found the coaly shale impoverished in pollen and spores, but containing an unnamed species of the dinoflagellate *Deflandrea*, indicating a probable Senonian age. This age supports the writer's preference that the section is basal Tent Island Formation, or Cuesta Creek Member.

In the area of Deep Creek, D.K. Norris collected shale samples from the Tent Island Formation for microfossil analysis. These samples (GSC locs. C-9784 to C-9788) were examined and reported on by T.P. Chamney, who found a sparse microfauna consisting of:

Haplophragmoides n. sp.
H. sp. 88
?*H.* sp.
?*Trochammina* sp.
Hippocrepina sp.
H. (Pelosina) sp. 6
Bathysiphon sp.
Saccammina sp. 2

This assemblage of foraminifers was dated as Senonian (probably Santonian-Campanian) by Chamney.

Thus, west of Blow River, where it is much thicker than it is in the type area, the Tent Island Formation may be as old as Santonian. If this is true, the Cuesta Creek Member is not the same age everywhere, but is younger in the Big Fish River area than in the region northwest of Blow River.

Moose Channel Formation

The Moose Channel Formation, established by Mountjoy (1967a, p. 8), comprises "about 1,200 feet of nonmarine, loosely consolidated sandstones occurring along the Arctic Coast in a belt extending for about 10 miles on either side of the mouth of Fish River". He designated as the type section the exposures along Big Fish River, although no detailed measurements and descriptions were made because of lack of time during the 1962 field season. Also included in the original description of the Moose Channel Formation were coaly beds outcropping in the banks of Aklak Creek, stratigraphically higher than the rocks on Big Fish River. These beds are designated here the Aklak Member, and assigned to the Reindeer Formation. A mudstone-dominated unit, lying stratigraphically below the Aklak Member, is termed the Ministicoog Member. It is partly exposed near the mouth of Big Fish River. The basal sandstone member, which forms the steep-walled gorge at the confluence of Little Fish (Cache) Creek and Big Fish River, is left unnamed. The thickness of the Moose Channel Formation at the type section is approximately 3,000 feet (900 m).

Besides outcropping in the vicinity of Big Fish River the Moose Channel also appears in the banks of Eagle Creek, whose mouth is located 14 miles (22.4 km) northwest of the mouth of Big Fish River (Fig. 1). Approximately 2,400 feet (730 m) of Moose Channel strata were measured on Eagle Creek (Secs. 7, 8).

The Moose Channel Formation also occurs in Deep Creek Syncline about 50 miles (80 km) west-northwest of the mouth of Big Fish River on the coastal plain (Fig. 2). The resistant sandstone beds of the formation distinctly outline the syncline and cause the outcrop area to be somewhat elevated above the surrounding plain. Outcrops here are rare, however, because extensive physical weathering has reduced the rock to a thick fragmental mantle. Graphic measurements were made from vertical air photographs and structural data obtained from three ground traverses. A total thickness approximating 2,250 feet (690 m) is indicated for the Moose Channel Formation in this area (Sec. 9).

The Moose Channel Formation underlies the lower Mackenzie Delta where it probably is preserved extensively, based on information from the boreholes drilled there. In the I.O.E. Ellice O-14 well, strata assigned to the Moose Channel occur in the interval 5,610 to 9,160 feet (1710-2790 m). Sandstones occurring at the bottom of the hole just below 9,160 feet (2790 m), also may belong to the Moose Channel Formation. Thus, the indicated thickness of the Moose Channel Formation here seems to be relatively greater than that of the outcrop sections, even though sandstones are relatively attenuated by the abundance of mudstone.

In the Reindeer D-27 borehole the Moose Channel is represented by only 1,480 feet (452 m) of section in the depth-interval 5,101 to 6,220 feet (1530-1895 m).

An isopach map (Fig. 8) of the combined basal sandstone and Ministicoog members indicates a lenticular sedimentary packet that thickens seaward and is thickest offshore in line with the Yukon-Northwest Territories boundary. This thickness maximum coincides approximately with the high negative gravimetric anomaly (Sobczak *et al.*, 1973) that is centred over the mouth of Shallow Bay.

The lower contact of the Moose Channel Formation is taken at the base of a relatively continuous sequence of sandstone and conglomerate beds. This is generally distinct and sharp (Figs. 9, 16) in the outcrop area, and may be erosional in places. The lower contact is gradational above the Tent Island mudstone in the Ellice O-14 borehole, and in the Reindeer D-27 borehole at a depth of approximately 6,220 feet (1895 m).

Basal sandstone member

In the vicinity of lower Big Fish River the basal sandstone member forms resistant ridges and steep-walled gorges because of its large proportion of durable sandstone. Sandstone comprises more than 85 per cent of the 1,920-foot (595 m) thickness exposed on Big Fish River (Sec. 4), while the remainder consists mainly of intercalated, thin grey shale beds. Toward the northwest, the basal member becomes less sandy and resistant, and thins

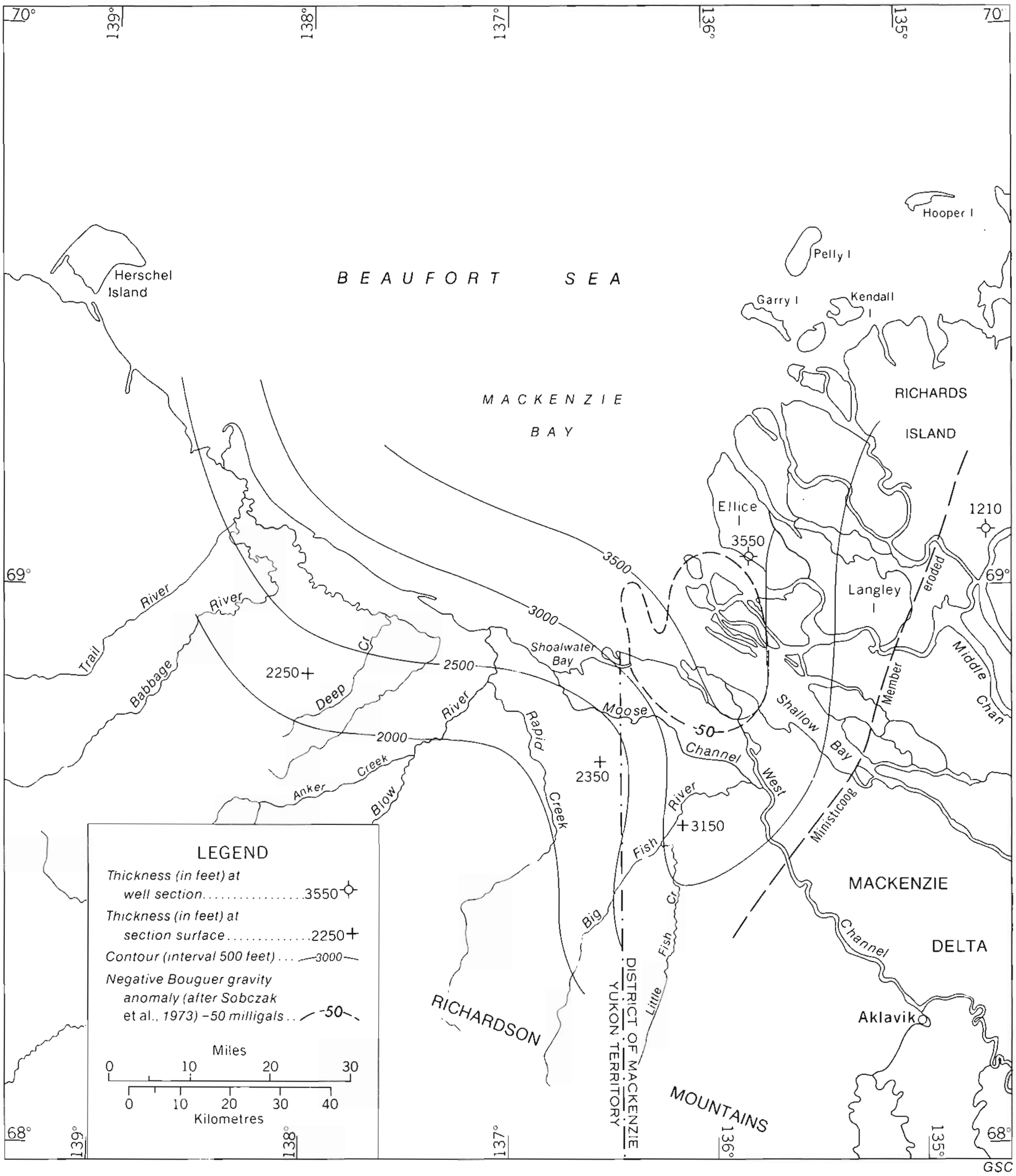

Figure 8. Isopach map of combined basal sandstone and Ministicoog Members, Moose Channel Formation

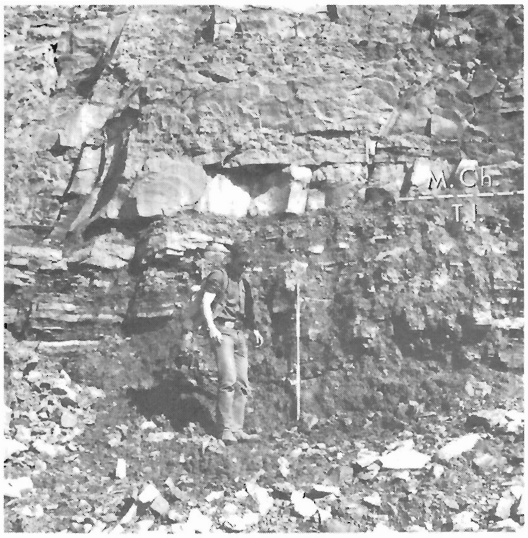

Figure 9. Lower contact of Moose Channel Formation on Tent Island Formation, Little Fish (Cache) Creek. GSC 202503

to only 1,250 feet (381 m) on Eagle Creek (Sec. 7). There, the basal member is nearly all sandstone in the top 460 feet (140 m) but, in the lower part, consists of alternating beds of mudstone, sandstone, conglomerate, and rare coal.

In the subsurface section of the Ellice O-14 borehole, the basal sandstone member is 2,375 feet (725 m) thick (depth-interval 6,785-9,160 feet, 2067-2792 m), but may be only 1,210 feet (370 m) thick (depth-interval 5,010-6,220, 1527-1895 m) in the Reindeer D-27 borehole. In both places the member consists of alternating sandstone-dominated and mudstone-dominated units, and consists of approximately 40 per cent sandstone.

In outcrop the basal sandstone member is characterized by light grey, fine- to coarse-grained sandstone composed of quartz, chert and feldspar and rich in lithic fragments of various kinds. Scattered pebbles and pebble-lenses are common features in the sandstone beds. This sandstone reacts to weathering processes in various ways, including the formation of irregular flags or slabs, development of friable, non-bedded sand, and the retention of very thick to massive, unfractured beds. Detailed description of the sedimentary features associated with this member are discussed in the chapter on Sedimentology.

In the Ellice O-14 borehole section the lower half of the basal member contains far more sandstone and conglomerate than the upper half, which is practically devoid of conglomerate. The sandstone is mainly fine to medium grained, moderately to well sorted, grey, black-speckled, and rarely visibly porous. Argillaceous, silty, carbonaceous, very fine grained sandstone beds also are present, commonly interbedded with coarser varieties. The basal half contains chert-pebble conglomerate beds, silty and sandy, dark brownish grey mudstone, and rare coal seams. The upper half is dominantly siltstone and silty mudstone, commonly with abundant carbonaceous particles. Calcareous and glauconitic sandstone beds are present in this interval.

Ministicoog Member

The interbedded grey mudstone and siltstone unit (Fig. 10) that overlies the basal sandstone member, and was referred to previously as "the coaly mudstone member" (Young, 1971), and Unit 4 (Holmes and Oliver, 1973), is herein formally defined as the Ministicoog Member. The type section is located at the lower end of Big Fish River (Sec. 5) where the uppermost 250 feet (76 m) are absent and the remainder is poorly exposed. To accomodate these shortcomings, other cutbanks in the vicinity of Big Fish River are designated as part of the type area, and the I.O.E. Ellice O-14 borehole section in the depth-interval 5,610-6,780 feet (1710-2070 m) is selected as the reference subsurface section. The member is named after Ministicoog Channel which flows a few miles northeast of the type section.

The thickness of the Ministicoog Member in the type area is approximately 1,200 feet (366 m) of which the lower 940 feet (287 m) can be studied in the banks of Big Fish River near its mouth (Sec. 5, Appendix).

The upper 250±20 feet (76±6 m) were calculated graphically from the map (Fig. 1). It is 1,170 feet (357 m) thick in the Ellice O-14 borehole, 1,100 feet (336 m) on Eagle Creek, and 1,000±50 feet (305±15) at Deep Creek Syncline, 50 miles (80 km) west-northwest of the type area. In the Reindeer D-27 borehole it may be represented by only 210 feet (63 m) in the depth-interval 4,740 to 4,950

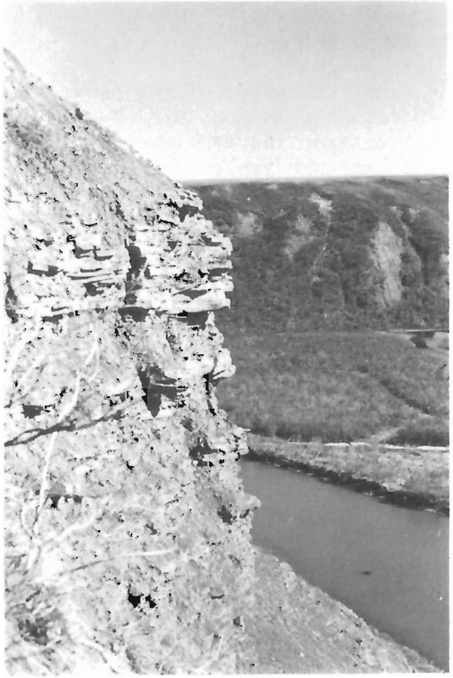

Figure 10. Mudstone facies of Ministicoog Member, Moose Channel Formation, on lower Big Fish River. GSC 199049

feet (1448-1510 m) or, alternatively, it may be absent completely as indicated on the correlation diagram. In either case, this marked thinning probably is due to erosion prior to deposition of the overlying Reindeer Formation.

The contact with the underlying basal sandstone member is gradational and picked at the top of the well-bedded or massive sandstone. At the type section this contact is distinctive. To the northwest at Eagle Creek, however, the contact is difficult to pick because of the large content of sandstone in the Ministicoog Member.

The upper contact of the Ministicoog Member generally is abrupt and marked by a distinct change in lithology from mudstone to sandstone or conglomerate of the overlying Reindeer Formation. This abruptness is well displayed at the Eagle Creek section where resistant conglomerate and sandstone directly overlie recessive coaly shale and mudstone of the Ministicoog. The coarse clastic beds are convoluted just above the contact, indicating that the underlying muds were still soft and water-saturated when the coarse clastics were superimposed on them. A similar phenomenon was observed on Aklak Creek. Thus, fairly continuous sedimentation from the Ministicoog into the Reindeer Formation is evident at these localities.

Paleontology and age

Except for their traces, no macrofossils have been found yet in the Moose Channel Formation. However, fossil plant remains, pollen and spores, and microfauna have been collected and studied by numerous paleontologists, and their identifications form the basis of the following discussion of ages of the various members of the Moose Channel Formation.

Basal sandstone member

The sandy character of the basal sandstone member has resulted in poor microfossil preservation, and no samples from the type area have yielded material suitable for age assignments.

A few plant leaves were recovered from coaly shale in the basal sandstone member on Eagle Creek near its junction with Mackenzie Delta. These were identified by C.J. Smiley of the University of Idaho as *Metasequoia cuneata*, which he reports is a Late Cretaceous to Early Tertiary species in North America. Another collection from a different fault-block on Eagle Creek (GSC loc. C-11283) yielded *Esquisetites* sp., also found in the Aklak Member.

Strata in the I.O.E. Ellice O-14 borehole, believed to be correlative with the basal sandstone member have been somewhat more productive in pollen and spores. Samples of cores at depths of 8,873, 9,485 and 9,520 feet (2710, 2895, and 2905 m) contained dark brown plant debris from which Brideaux (1973) was unable to determine an age. However, samples from core No. 9 in the depth-interval 7,870-7,920 feet (2400-2420 m) (GSC locs. C-12667, C-12669, C-12675) yielded the following assemblage of palynomorphs:

Triporopollenites sp. AA = *T.* sp. cf. *T.* *rugatus* Newman
Taxodiaceaepollenites sp.
Betulaceoipollenites sp. AA = *B.* sp. cf. *B.* *infrequens* (Stanley) Norton and Hall
Diconodinium sp.
Cleistosphaeridium sp.
Podocarpidites sp.
Aquilapollenites sp.

Brideaux assigned a Late Cretaceous, Maastrichtian age, to this assemblage. Higher strata contained material of inconclusive character, but which suggested a pre-Paleocene age.

On the basis of the above idenfitications, the basal sandstone member is latest Cretaceous (Maastrichtian) in age.

Ministicoog Member

Many samples from lower Big Fish River and Aklak Creek were prepared for palynological analysis but were reported by Brideaux to be either barren or "full of" recycled and non-diagnostic pollen and spores. A single sample from lower Eagle Creek (GSC loc. C-11272) contained the following forms:

derived Early Cretaceous trilete spores
Sphagnumsporites (Stereisporites) australis *parva* (Cookson) Potonié
Inaperturopollenites hiatus (Potonié) Thomson and Pflug
Stereisporites psilatus (Ross) Pflug
S. antiquasporites (Wilson and Webster) Dettmann
Triporopollenites sp. cf. *T. costatus* Norton
Betulaceoipollenites sp. cf. *B. infrequens* (Stanley) Norton and Hall

Brideaux assigned this assemblage to the Upper Cretaceous, probably Maastrichtian Stage, based on the occurrence of *T.* cf. *T. costatus* and *B.* cf. *B. infrequens*.

At the top of the member on Aklak Creek (GSC loc. C-11298) shale samples yielded recycled early Paleozoic spores, recycled Early Cretaceous pollen and spores, and *Triatriopollenites* sp. cf. *T. costatus* Norton. This was dated as Late Cretaceous, probably post-Senonian in age by Brideaux.

In the I.O.E. Ellice O-14 borehole, core No. 7 is believed to be from the Ministicoog Member, and samples analyzed for palynology by Brideaux (1973) yielded the following forms (GSC loc. C-12662, depths 6,280-6,284 feet, 1914-1915 m):

derived Cretaceous and Late Permian-Early Triassic species
Aquilapollenites spp.
Sequoiapollenites spp.
Stereisporites sp.
Taxodiaceaepollenites sp.
rare trilete spores

This assemblage was dated by Brideaux as Maastrichtian or possibly Campanian in age. Slightly lower in the core (6,304-6,308 feet, 1921-1922 m), another sample (GSC loc. C-12664) yielded:

derived Early Cretaceous and older spores
Spiniferites ramosus (Ehrenberg) Mantell
Aquilapollenites spp.
Lycopodiumsporites sp.
Osmundacidites sp.
Taxodiaceaepollenites sp.

This sample cannot be dated precisely, but is considered by Brideaux to be pre-Paleocene in age.

Detailed sampling for micropaleontological analysis was carried out by T.P. Chamney on lower Big Fish River. A cursory examination of the material indicates the presence of numerous new foraminiferal assemblages (Chamney, 1972) which will require careful study; tentatively, he assigned the formation to the upper part of the Upper Cretaceous or possibly Tertiary (written com., 1972).

In view of the above reconnaissance micropaleontological studies, the Ministicoog Member is likely of Maastrichtian age.

Reindeer Formation

Aklak Member

On Yukon Coastal Plain the Aklak Member is generally the uppermost stratigraphic unit, except for Pleistocene deposits, and its top is everywhere eroded. The Aklak Member, referred to previously as the "coal-bearing member" (Young, 1972) and Unit 5 (Holmes and Oliver, 1973) of the Moose Channel Formation, was included in that formation in the original discussion by Mountjoy (1967a). This assignment is amended here in the light of subsurface correlations beneath Mackenzie Delta; the Aklak Member now is considered to be a basal member of the Reindeer Formation.

Mountjoy (1967a) proposed the name Reindeer Formation for about 550 feet (167 m) of poorly consolidated, nonmarine clastic sediments containing lignite coal, exposed in the Caribou Hills east of Mackenzie Delta. These rocks contain indigenous Paleocene pollen and spores (ibid.; W. Brideaux, written com.) which are distinctly younger than palynomorph assemblages from the type Aklak Member. Several borehole sections, however, penetrate over 4,000 feet (1200 m) of Reindeer Formation, and these beds range in age from Maastrichtian to Eocene or Oligocene (Brideaux, 1973), which indicates the incomplete nature of the surface sections. Because the Aklak delta-plain facies may be distinct areally from that at the type Reindeer section, and because both may grade into a common transitional marine facies, it is considered wise at this time to denote the western deltaic facies by the name Aklak Member.

The Aklak Member has been observed at three localities west of Mackenzie Delta. These include the type section on Aklak Creek, which flows into the southern end of Coal Mine Lake; Eagle Creek (at Lat. 68°42'00"N, Long. 136°32'00"W); and the axial part of Deep Creek Syncline.

The type section lacks an upper contact, but was selected because of the characteristic diverse lithology, good fossil recovery, and ease of access. The Aklak Member is exposed in the banks of Aklak Creek for about 2 miles (3.2 km) above its mouth, and attains a thickness of approximately 1,900 feet (580 m). On aerial photograph A14361-44, its top is at X=-4.05, Y=+2.70 cm, and base at X=-5.40, Y=+0.98 cm. This section (Sec. 6) lies within an outcrop zone about 2 miles (3.2 km) wide marginal to the western side of Mackenzie Delta and marked by brilliant red cutbanks of ancient bocannes, or hematitic sintered mudstone.

A few miles to the northwest at Eagle Creek, the basal 685 feet (209 m) of the member is exposed and consists of resistant sandstone and conglomerate beds. This section is overlain abruptly by a recessive and covered interval, suggesting a vertical stratigraphic change to mudstone. Similarly, farther west at Deep Creek Syncline, the Aklak equivalent is about 600 feet (180 m) thick, and is overlain abruptly by recessive strata.

The basal contact of the Reindeer Formation is distinct in all sections studied, and is conformable in the Yukon Coastal Plain area. This appears to be true, also, for the Ellice Island area because the contact in the I.O.E. Ellice O-14 borehole-section is slightly gradational and conformable. On the eastern side of Mackenzie Delta, however, the basal contact is unconformable, as exemplified by angular discordance at the contact at a depth of 5,010 feet (1530 m) in the Reindeer D-27 borehole.

The Aklak Member is characterized by alternating units of conglomerate, sandstone, siltstone, shale and coal, suggesting a fluvial and delta-plain facies. Its lateral and upper limits are defined by changes in facies either to those dominated by mudstone or by marine characteristics. This change probably occurs at various levels above the base at different places. In the Ellice O-14 section, the Aklak Member comprises the strata forming the almost continuous succession of nonmarine depositional cycles from the base of the Reindeer Formation to its top at a depth of 1,160 feet (354 m).

Sandstone predominates in the member, and varies from friable to well consolidated both in outcrop and in the subsurface. Sandstone of the Aklak Member appears to be paler and more speckled than that of the Moose Channel Formation, which commonly displays tones of yellow, orange, green or red. The feldspar content is about 5 per cent or less, which is about one-half that occurring in the Moose Channel, and the chert content is about twice as great as in the latter formation (*see* discussion under heading Sandstone petrography). The Aklak sandstones are commonly conglomeratic with phenoclasts up to 3 centimetres maximum diameter; both pebble- and cobble-conglomerate interbeds are present.

Red siltstone and shale with leaf impressions are associated with bright red bocannes in the type section. The hematite content of these rocks is due probably to the heating induced during the combustion of the nearby bocannes. The latter are partly brecciated and appear as red to dark brown cinders in outcrop. No smouldering bedrock occurs in this area today.

The Aklak Member is important economically for its coal seams, one of which was mined at Coal Mine Lake for many years to supply fuel for the village of Aklavik. The coal content of the Aklak is much greater than that of the Moose Channel Formation, despite the similarity in lithotopes.

Paleontology and age

The Aklak Member contains a relatively abundant flora and microflora, but an impoverished microfauna, due largely to its dominantly nonmarine origin in a delta-plain depositional environment. Leaf fossils were collected on Aklak Creek during Operation Porcupine and were identified by W.A. Bell of the Geological Survey of Canada (Mountjoy, 1967a). Bell reported the following taxa in the collections (GSC locs. 6613-6615):

Trochodendroides (Cercidiphyllum?) arctica (Heer) Berry forma *richardsoni*
Equisetum sp.
Taxodium gracile Heer

Commenting on the age indications of this collection, Bell stated the "*T. arctica* is ... common in the Paleocene".

Two plant fossil collections were made recently from the same locality and were examined by C.J. Smiley of the University of Idaho. In the first collection he reported (GSC loc. C-11280) "mostly 'coalified' stems and plant debris, with a few fragmentary and poorly preserved specimens resembling the following taxa":

?Cyperacites sp.
?Potamogeton sp.
?Nelumbites sp.
?Parataxodium or *?Metasequoia* (isolated needles only ...)
?Equisetites sp.

Smiley commented that this collection affords a "good correlation with floral records from non-marine units that interbed with the top of the marine Schrader Bluff Fm. (the Sentinel Hill Member) along the Chandler and Colville Rivers. (The collection) correlates with lower part of Kogosukruk Tongue of the Prince Creek Formation, between two marine units that contain *Inoceramus patootensis* and *I. steenstrupi*. (It is) apparently near the boundary between my Zones VI and VII, from available floral records". Smiley's Zones VI and VII lie within the Santonian to Maastrichtian Stages of the Upper Cretaceous (Smiley, 1969a, Fig. 3) and Jeletzky (1971a; pers. com.) has confirmed that these pelecypods are good indicators of the Santonian and possibly early Campanian Stages in Canada. However, these fossils occur in rocks older than the Aklak (e.g. Kanguk Formation, Jeletzky, op. cit.) and palynological research on the Aklak (*see* below) indicates an age considerably younger than Santonian. Hence, the Aklak's flora must be younger than similar floras of the Alaskan north slope.

Palynological studies on rocks of the Aklak Member were made first by D.C. McGregor who examined spores and pollen in coal samples supplied by B.A. Latour from Moose River Mines on Coal Mine Lake (Mountjoy, 1967a). He reported that the assemblage had a pre-Tertiary aspect, and "an age within the upper half of the Upper Cretaceous is considered most likely".

Recently, a more complete reconnaissance examination of the palynology of the Aklak Member was undertaken by W.W. Brideaux. An assemblage from a coaly sample collected about 100 feet (30 m) above the base of the type section on Aklak Creek consists of (GSC loc. C-11299):

Stereisporites antiquasporites (Wilson and Webster) Dettmann
Sphagnum (Stereisporites) regium Drozhastichich *in* Samoilovitch *et al.*
Inaperturopollenites hiatus (Potonié) Thomson and Pflug
Laricoidites magnus (Potonié) Potonié, Thomson and Thiergart
Sequoiapollenites paleocenicus Stanley
Sequoiapollenites sp. A
Sequoiapollenites sp. B
Triatriopollenites sp. cf. *T. costatus* Norton
Betulaceoipollenites sp. cf. *B. infrequens* (Stanley) Norton and Hall = *B.* sp. AA
Triporopollenites sp. cf. *T. rugatus* Newman = *T.* sp. AA

Brideaux referred this assemblage to the Maastrichtian or the early Paleocene and comments that it "resembles most those described from uppermost Cretaceous or lowest Paleocene deposits of the western interior United States and adjacent Western Canadian plains and foothills".

An almost identical pollen assemblage was recovered by Brideaux (1973) in the I.O.E. Ellice O-14 borehole at a depth of 4,850 feet (1480 m) (GSC loc. C-12661). In this suite he identified the following:

Sequoiapollenites sp. A
Sequoiapollenites sp. B
Sphagnum (Stereisporites) regium Drozhastichich *in* Samoilovitch *et al.*
Laevigatosporites ovatus Wilson and Webster
Triporopollenites sp. AA = *T.* cf. *T. rugatus* Newman
Betulaceoipollenites sp. AA = *B.* cf. *B. infrequens* (Stanley) Norton and Hall
Taxodiaceaepollenites sp.
various bisaccate pollen
derived Early Cretaceous species

This assemblage allows direct correlation between a subsurface section and a key surface section (Fig. 28).

Stratigraphically higher in the type section, Brideaux found pollen and spore assemblages very similar to the one near the base of the member. The youngest beds sampled at the type section, approximately 1,500 feet (456 m) above the base, yielded the following forms (GSC loc. C-19561):

Triporopollenites sp. AA
Betulaceoipollenites sp. AA
Cranwellia striata Srivastava
Lycopodiumsporites sp.
Triporites spp.

Alnipollenites? sp.
recycled Carboniferous and Early Cretaceous species

This was dated by Brideaux as Maastrichtian or possibly early Paleocene in age.

It is of interest to note that a coaly sample collected by D.K. Norris (1972a, p. 97) from a structurally discordant outcrop in the Deep Creek Syncline (Lat. 68°53'N, Long. 138°02'W) yielded a pollen assemblage identified by Brideaux as follows (GSC loc. C-11263):

Deltoidospora spp.
Osmundacidites spp.
Cycadopites spp.
unidentified bisaccate pollen (Abietineaceous types)
Inaperturopollenites hiatus (Potonié) Thomson and Pflug
Betulaceoipollenites sp. cf. *B. infrequens* (Stanley) Norton and Hall = *B.* sp. AA
Tricolpites sp.
Triporopollenites sp. AA = *T.* sp. cf. *T. rugatus* Newman

This assemblage is indistinguishable in age from those of the type Aklak Member, according to Brideaux (pers. com., 1973). Palynological research by Brideaux on both the type Aklak and type Reindeer Formation of Caribou Hills shows that the type Reindeer is definitely younger. He comments that "the pollen species from the Caribou Hills (Reindeer Formation) location represent a more modern parent flora than do those from sections on Aklak Creek. Although sections at Aklak Creek may be in part of Paleocene age, they are likely very early Paleocene and are definitely older than Paleocene material from the Reindeer Formation at Caribou Hills. The occurrence in some samples from Aklak Creek of *Aquilapollenites* spp. and *Cranwellia striata*, generally taken to indicate Maastrichtian or at most very early Paleocene age, support this view".

In summary, the fossil flora support a latest Cretaceous age for the Aklak Member in outcrop occurrences on Yukon Coastal Plain. A lower limit is suggested by leaves and stems which are similar to those found in the lower Kogosukruk Tongue of Alaska's north slope. This unit intertongues with marine shale containing *Inoceramus patootensis* and *I. steenstrupi*, dated as Santonian to earliest Maastrichtian.

On the other hand, a younger age is suggested by Bell who examined similar flora and found it containing elements of both Late Cretaceous and early Tertiary floras. The palynology of the formation indicates a Maastrichtian to very early Paleocene age, and the possibility exists that the Cretaceous-Tertiary boundary lies within the unit at the type section.

Since the Aklak Member comprises the entire Reindeer Formation in the I.O.E. Ellice O-14 borehole (depth-interval 1,160-5,610 feet, 353-1709 m), the age of the Aklak ranges up into the Eocene and possibly the Oligocene according to Brideaux (1973, GSC locs. C-12656 to C-12660).

SEDIMENTOLOGY OF FISH RIVER GROUP AND REINDEER FORMATION

These discussions are based on well-exposed surface sections and traverses in the mapped area near Big Fish River, and one subsurface section (I.O.E. Ellice O-14). Only the major sedimentary environments are described, with one or two good examples of each used for illustration. The main bases used for interpreting lithofacies are sedimentary structures, visible textures, and vertical sedimentary sequences; no grain size analyses were attempted. The latter were performed and integrated into the interpretation of sedimentology by Holmes and Oliver (1973) whose research and interpretations are completely independent from those of the writer.

TENT ISLAND FORMATION

The Tent Island Formation is dominated by mudstone and siltstone but pebbly mudstone and interbedded sandstone and mudstone are common in its basal part. The basal Cuesta Creek Member consists of minor amounts of all the above, as well as sandstone and a mixed conglomerate and sandstone facies. These deposits apparently are related closely in a paleogeographic sense because any two may occur in vertical contiguity. This characteristic is well demonstrated by the succession at the type section on Big Fish River (Fig. 6).

Description of lithofacies

Conglomerate-sandstone facies

This facies was observed in the Cuesta Creek Member on Big Fish River, Hornet Creek, and near the head of Deep Creek. Conglomerate and sandstone beds commonly form the basal few feet of the formation where the Cuesta Creek Member is dominantly sandstone.

In the type section, on Big Fish River, conglomerate and sandstone comprise 30 feet (9.1 m) near the middle of the Cuesta Creek Member, and the entire 67 feet (20 m) of its uppermost unit. Across the river, a distance of 2,000 feet (610 m), conglomerate and sandstone comprise 63 feet (19 m) of the lower unit, partly in the form of a channel-fill sequence. Where the scour is deepest the infilled clastics form a fining-upward sequence of sediments. The basal 13 feet (4 m) form a single bed of coarse pebble-conglomerate which has a coarse-grained sand matrix. The upper two feet of this lens grade laterally into conglomeratic sandstone with flat mud-clasts up to 1 foot (30 cm) wide. Overlying this bed are 11 feet (3.4 m) of sandstone which are medium grained and contain abundant mud clasts. Even, parallel laminations are present in the top 4 feet (1.2 m) of this unit. Above this are 3 feet (1 m) of soft, shale-parted sandstone with ripple-laminations. Such a sequence of sediments and associated structures is typical of fluvial deposition (Allen, 1965), in which a gradual upward decrease in flow regime is exhibited.

Overlying this sequence the coarse sediments are more like the typical facies elsewhere which

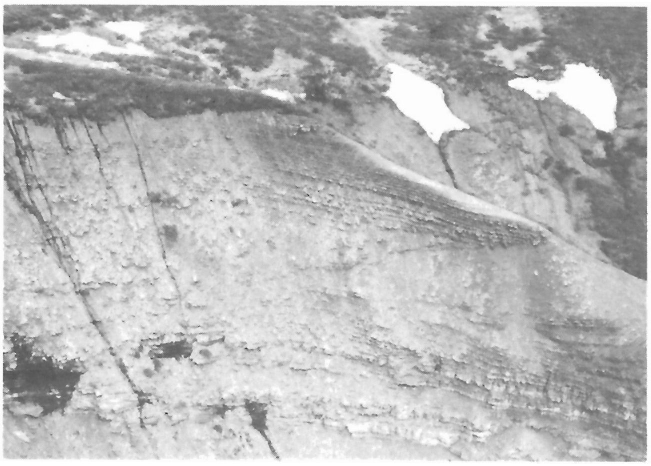

Figure 11. Inclined beds of sandstone-mudstone facies, Tent Island Formation, Big Fish River. A low-angle fault bisects pictured section and gives the false impression of original basin floor overlain by foreset beds. GSC 199064

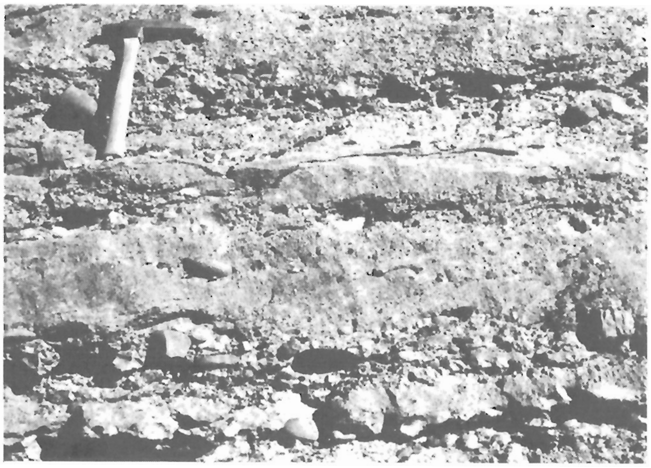

Figure 12. Irregular interbeds of conglomerate and sandstone, Cuesta Creek Member. GSC 199065

consists of lenticular, intertonguing beds of conglomerate, pebbly sandstone, sandstone and, rarely, shale. Rapid lateral gradations from conglomerate to sandstone are common and, in places, sandstone beds split into several extensive thin beds, each divided by a lens of conglomerate or shale (Fig. 12). Phenoclasts exhibit a wide range in size at a given locality and commonly have maximum diameters between 1 and 3 feet (0.3-1.0 m). Mudstone clasts of local derivation are common. Imbrication of phenoclasts is sometimes discernible, but generally the longest diameters are aligned roughly parallel to bedding.

Coarse, poorly sorted clastic beds, which grade rapidly in texture laterally, are characteristic of braided stream deposition (Smith, 1970). Because of the limited areal extent of this facies within the formation, the streams must normally have been relatively small, but occasionally were imbued with high discharge-rates in order to have transported boulder-size clasts.

Sandstone facies

Uniform sandstone units dominate the Cuesta Creek Member in the Rapid Creek-Hornet Creek area in contrast to the conglomerate predominating in the type area. Beds of sandstone range in thickness from a few inches to about 3 feet (1 m), and are commonly pebbly in the basal 1 to 2 inches (2.5-5.1 cm). These beds generally are uniform in appearance or are faintly parallel-banded with rare, shallow, tabular cross-stratification and current lineations. Coaly and carbonaceous plant debris is rare in this facies. Grain-size modes range from fine grained (0.25 mm diameter) to granular (4.0 mm), and the sands generally are well sorted, tightly packed and lack detrital matrix.

These textural and structural properties probably resulted from deposition in the littoral zone where wave activity and longshore currents reworked the sands. The lack of trace fossils or bioturbation usually associated with shoreface sands is puzzling, but not inconsistent with the generally abiotic nature of the underlying and overlying marine mudstone (*see* Chamney, 1972). Foreset orientations of crossbedding sets of Cuesta Creek (Fig. 29) show a bimodal distribution that is typical of littoral sand deposits (Klein, 1967). This interpretation is supported also by the gradual shale-out northward along the cuesta formed by the sandstone. Thus, the sandstone facies grades laterally and vertically into sandstone-shale facies of the basin's shallow marginal zone.

Sandstone-mudstone facies

This facies forms the basal unit of the formation in the type area, but is not present to the northwest where sandstone and conglomerate lie directly on the Boundary Creek Formation or Lower Cretaceous shale. Only on lower Rapid Creek where the Cuesta Creek Member shales out does this facies reappear. It forms, along with pebbly mudstone, the basal unit of the overlying mudstone member of the Tent Island Formation (Fig. 11).

Mudstone is the dominant rock-type of the facies and is typically brownish grey, silty and brittle. Siltstone and sandstone comprise thin beds which range up to one foot in thickness and exhibit sharp basal contacts along which are present current-formed structures such as current lineations, flute-casts and groove-casts. The beds are commonly parallel-laminated, contain abundant carbonaceous debris on parting surfaces, and grade upward into finer textured sediments. Ripple-laminations and climbing ripples were observed in places.

A single lenticular channel was observed within the facies on the southeastern bank of Big Fish River opposite the type section. This channel fill is 12 feet (3.7 m) thick at its axis, at least 100 feet (30 m) wide, and composed of conglomerate which grades laterally and upward into sandstone.

Figure 13. Two-stage scour in mudstone of Tent Island Formation, Hornet Creek. GSC 199062

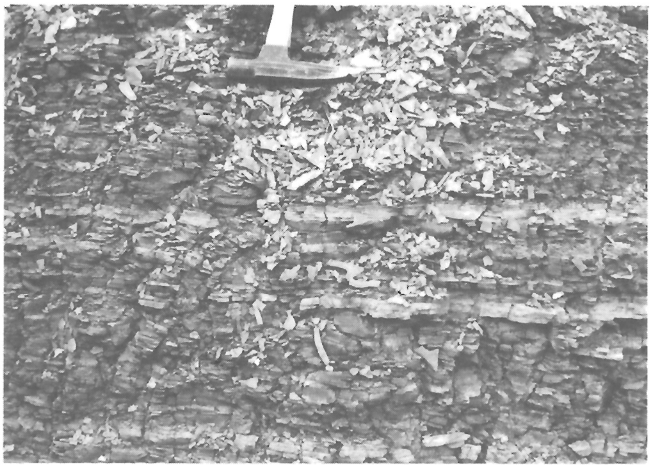

Figure 14. Mudstone with minor siltstone interbeds, Tent Island Formation. GSC 199063

Farther upsection the top of the basal sandstone-mudstone facies is scoured to a depth of 32 feet (10 m) by a major channel which, also, is filled with conglomerate and sandstone.

The scattered sandstone beds possess current-structures formed by traction-load carpets and turbidity currents. Because the basal unit is scoured and overlain with coarse detritus it is reasonable to conclude that sedimentation occurred on the foreslope of a prograding delta, whose topset deposits are the conglomerate and sandstone beds. Elsewhere, this facies is relatively thin and interfingers with the sandstone facies. In these cases it may represent sublittoral deposition in a non-deltaic situation.

Pebbly mudstone facies

In the type area pebbly mudstone and paraconglomerate ("tilloid" of Young, 1971) are common just above the Cuesta Creek Member (Fig. 7). On Little Fish (Cache) Creek this lithology grades upward into, or alternates with, sandy mudstone and shale. Small scours are present in places on the sharp bases of paraconglomerate beds. Burrow-structures are common in the sandy mudstone beds. These features indicate sedimentation from muddy slurries charged with pebbles and sand which flowed downslope partly as gravity flows, and partly as turbidity currents. The large scours referred to below also indicate that slumping occurred on unstable depositional slopes, giving rise to various gravity-induced deposits.

Scour structures

Near the base of the formation are pebbly mudstone beds, slump structures, and large-scale scours which occur in association with turbidite sandstone beds. A scour on Little Fish (Cache) Creek is steep-sided, at least 50 feet (15 m) deep, truncates sandstone beds dispersed in a mudstone unit, and is filled with uniform dark grey mudstone. On Hornet Creek, a two-stage scour is preserved (Fig. 13). The lower stage is truncated and overstepped by the upper stage and both are filled by alternating sandstone and shale beds. At both localities some sandstone beds truncated by the scours are convoluted, suggesting contemporaneous soft-sediment flowage when hydrostatic pressure was lowered locally by the sudden truncation of the beds.

Mudstone-siltstone facies

The dominant lithofacies of the Tent Island Formation consists of mudstone with scattered, thin siltstone beds present in proportions up to 25 per cent (Fig. 14). These beds have much the same characteristics throughout the formation. The siltstone commonly contains very fine sand, is calcareous and weathers to a dull orange-brown colour. Carbonaceous and micaceous flakes typically are concentrated in horizontal laminae. Parallel laminations, small-scale cross-laminations, and low-amplitude ripple-marks are characteristic of the beds, which vary in thickness from 1 to 10 inches (2.5-25 cm). In places, beds are markedly lenticular, but generally reasonably persistent laterally.

These structures evidently were produced by a low-energy traction carpet, probably developed at the distal ends of turbidity currents (Walker, 1967). Storm-induced suspensions (Reineck and Singh, 1972) may have caused some of the beds, but the cross-laminations and ripple-marks in the upper parts of beds attest to the presence of bottom-currents at the time of deposition.

A peculiar variant of this lithofacies occurs in the upper part of the formation in association with uniform soft mudstone. It consists mainly of alternating, very thin beds and lentils of poorly consolidated sandstone, brittle brown silty mudstone, and soft grey clay. Such units have a variegated appearance, weathering to yellow, orange, light grey, brown, and olive-green. Laminae rich in black, coaly or carbonaceous particles are abundant and rare coal laminations are present. Thin, lenticular beds of pebbly mudstone, conglomerate and argillaceous sandstone are present in minor amounts. Rarely, sulphur- and sulphate-cemented conglomerate or sandstone is observed. Cross-laminations and burrows are rare. The frequent, small-scale alternation of sediment-types reflects extremely variable conditions of clastic supply. This may be due to one or more rivers supplying sediment to the basin under conditions of widely varying discharge. A stormy coastline also could result in intermittent coarse suspension deposits, but the presence of plant debris indicates a nearby fluvial source for the sediment. Bottom currents evidently were almost absent except for sporadic gravity-flows which introduced coarse material in the forms of pebbly mudstone and lenticular sandstone.

General interpretation

The widespread areal extent and the generally pelitic character of the Tent Island Formation, as well as its indigenous foraminiferal and dinoflagellate microfauna, indicate a shallow-marine environment with relatively open circulation.

Initially, sedimentation was partly nonmarine, and the Cuesta Creek Member conglomerate and sandstone were deposited in valleys and low areas on the erosional surface by small braided streams. Small deltaic wedges of sediment, represented by the sandstone and mudstone facies and associated littoral and fluvial coarse clastics, were deposited locally at the mouths of relatively small rivers.

Continued subsidence of the basin occurred such that the present coastal plain area was inundated, and sedimentation lagged behind the ever-deepening waters. The common occurrence of carbonaceous material and sand in the sediments suggests that deposition occurred mainly relatively close to the shore. However, a formation of this extent and thickness could not have been deposited close to shore all at the same time. Hence the strong possibility exists that the formation was built up by a stacking of laterally prograding pelitic wedges. Support for this hypothesis is provided by the existence of conglomeratic and sandy beds in the midst of the mudstones, as on Little Fish (Cache) Creek, and by the presence of pebbly mudstones with large scour-structures at various levels within the formation.

MOOSE CHANNEL FORMATION

The major lithotopes recognized in the Moose Channel include alluvial, progradational deltaic, littoral, and marine basinal environments. The latter is confined mainly to the Ministicoog Member, but shallow-marine sediments may be present also in the basal member in the Ellice O-14 well. Similar depositional environments are interpreted from facies in the Aklak Member of the Reindeer Formation, which also contains aggradational alluvial deposits.

Basal sandstone member

Alluvial lithotope

The alluvial sedimentary environment can be subdivided into two distinct facies; the diversified alluvial and coarse sandstone facies. The former denotes a facies whose diverse lithology reflects gradual upward accumulating sediment (vertical accretion) under a variety of conditions; the latter is a dominantly sandstone facies which accumulated by the lateral migration of fluvial point-bars and braided channel deposits (lateral accretion).

Diversified alluvial facies

The main characteristics of this facies are its diverse lithology and lack of uniformity both vertically and laterally. Rock types include cobble-conglomerate, coarse- and fine-grained sandstone, siltstone, mudstone, and carbonaceous shale. Several types of sedimentary assemblages recur in a measured section through this facies, and are described below.

The first type of assemblage is extremely diverse, consisting of lithologically different beds in succession. For example, in the interval 760 to 790 feet (232-241 m) of the Eagle Creek section (Sec. 7), the following sequence was observed; black, carbonaceous shale with leaf impressions and an overlying unit of interbedded sandstone and mudstone are locally eroded and overlain by very poorly sorted, mélange-like, cobble-conglomerate. This, in turn, is overlain by grey shale with thin, fine-grained sandstone beds and thicker, very fine grained, cross-stratified sandstone beds. Such variations in lithology reflect ever-changing physical and chemical conditions, such as those expected near a river with a wide range of discharge rates. During maximum flow periods channel-avulsion occurs and temporary channels are formed on the floodplain, leaving sand and gravel deposits; subsequent periods of low discharge result in the accumulation of mud and organic debris.

A second type contains abundant mudstone, with very thin laminations of sand, silt and coaly fragments. Thin, graded beds of fine-grained sandstone with ripple-marks and parallel laminations occur. The mud is sulphurous in places. This type of sedimentary unit is considered to have been formed in a floodplain lake, in which periodic influxes of coarser clastic material appeared from overflowing nearby fluvial or distributary channels.

The final important type of assemblage [commonly 10 to 25 feet (3.0-7.5 m) thick] consists mainly of sandstone. The upward succession above a basal scoured contact is (i) pebbly, coarse-grained sandstone; (ii) medium- to coarse-grained sandstone containing mud clasts; (iii) fine- to medium-grained, parallel-laminated sandstone with lenses of limonitic shale-clasts; and (iv) unconsolidated, limonitic sand. The sequence is overlain by mudstone with minor, thin sandstone beds.

Such a generally fining-upward sequence, in assocation with other fluvial and floodplain deposits, has been ascribed to the lateral migration of a meandering stream (Fig. 21, A) (Bernard and Major, 1963; Allen, 1965). The lowest, coarse clastic sediments were deposited in the stream channel or thalweg, the sandstone was built up on the sides of a laterally accreting point-bar, and the uppermost fine beds represent levee (with iron-enriched soil zones) and floodplain muds.

Figure 15. Thin, fining-upward rhythms in Moose Channel Formation. GSC 199057

Coarse sandstone facies

A large part of the Moose Channel Formation on Big Fish River consists of thick units of coarse-grained sandstone with minor amounts of pebble-conglomerate and argillaceous sandstone. Good examples of this facies are the intervals 450-605 feet (137-184 m), 750-1,120 feet (220-342 m), and 1,675-1,825 feet (512-557 m) above the base of the formation in Section 4.

The sandstone is generally coarse grained and moderately well sorted, but fine- to very coarse grained laminae and beds also occur. Structures common in these sandstone units include tabular cross-stratification in laterally extensive sets from 0.5 to 5.0 feet (0.15-1.5 m) thick, scour-and-fill structure exhibiting local erosion as much as 10 feet (3 m) deep, associated festoon cross-stratification, and carbonized wood fragments ranging from sand size to parts of logs several feet in diameter. This type of sandstone tends to split into thin, irregular slabs on weathered cliffs; massive sandstone beds are rare.

The characteristic pebble beds are tightly packed, usually about 1 foot (0.3 m) thick, have sharp, eroded, basal contacts and, in part, distinct upper contacts. In part, these beds form the bases of thin, fining-upward rhythms. Phenoclasts range in size from pebbles to boulders and are well rounded in both the conglomeratic beds and sandstone beds.

Near the top of the formation on Big Fish River a repetitive series of thin, fining-upward rhythms occurs within the facies (Fig. 15). A typical rhythm from the base upward consists of: (i) conglomerate or pebbly, coarse-grained sandstone with low-angle cross-stratification in sharp contact with underlying sediments, which grades up into (ii) fine- to medium-grained sandstone, overlain by (iii) shaly sandstone with ripple-marks and interbedded friable sandstone with plane laminations and scattered pebbles. The rhythms vary in thickness from 1.5 to 5.0 feet (0.46-1.52 m).

Similar, thin sedimentation rhythms occur in the Shawangunk Conglomerate of the Appalachian Mountains and are thought by Smith (1970) to have been deposited from braided streams. The irregular bedding, cut-and-fill structures, and rapidly varying grain size reflects rapidly fluctuating flow conditions associated with unconfined, braided channels.

The more generally sandy parts of this facies also are interpreted as having been deposited in non-cohesive fluvial channels, probably mainly of the braided type, in which longitudinal and transverse sand-bars comprise the dominant bed-form (Ore, 1965). These bars accrete mainly by lateral deposition on foreset slopes, resulting in planar cross-stratification similar to that commonly observed in the Moose Channel Formation. The frequent abandonment, migration, and re-occupation of fluvial channels in sandy alluvial plains result in the formation of scour-and-fill structures and lag gravels in channels. Very small amounts of overbank muds are preserved due, in part, to the constant lateral migration of channels. The presence of festoon crossbedding supports unidirectional flow (McKee, 1966; Visher, 1972) such as that associated with fluvial channels.

Deltaic lithotope

The deltaic lithotope includes the prodelta, delta fringe, distributary and interdistributary depositional environments. This lithotope is best developed in several surface sections at the base of the Moose Channel Formation, in the depth-intervals 7,750-8,075 (2360-2460 m) and 8,925-9,375 feet (2720-2860 m) in the I.O.E. Ellice O-14 borehole.

These intervals are characterized by a vertical profile in which prodeltaic muds become increasingly interbedded upward with silt and sand beds as a result of delta progradation. At the tops of the intervals the interbedded sediments grade into or are abruptly overlain by sandstone beds which represents distributary mouth and delta-front deposits. Farther upward, these sandstone beds, in places, grade into alluvial or delta-plain sediments. This vertical profile is expressed on electric logs of boreholes by a gradually upward increasing S.P. response, commonly accompanied by gradually increasing resistivity (Pirson, 1970, p. 36-58; Fisher, 1969, Fig. 7), a phenomenon well illustrated in the Ellice O-14 well at the intervals noted above.

Good riverbank exposures of this lithotope are present in the canyon of Little Fish (Cache) Creek and Big Fish River. The three stratigraphic sections examined in this area are correlated and shown diagramatically in Figure 16. At the southeast end of the exposures a complex of distributary channels and distributary-mouth-bar sand bodies overlie the prodeltaic muds but, to the northwest,

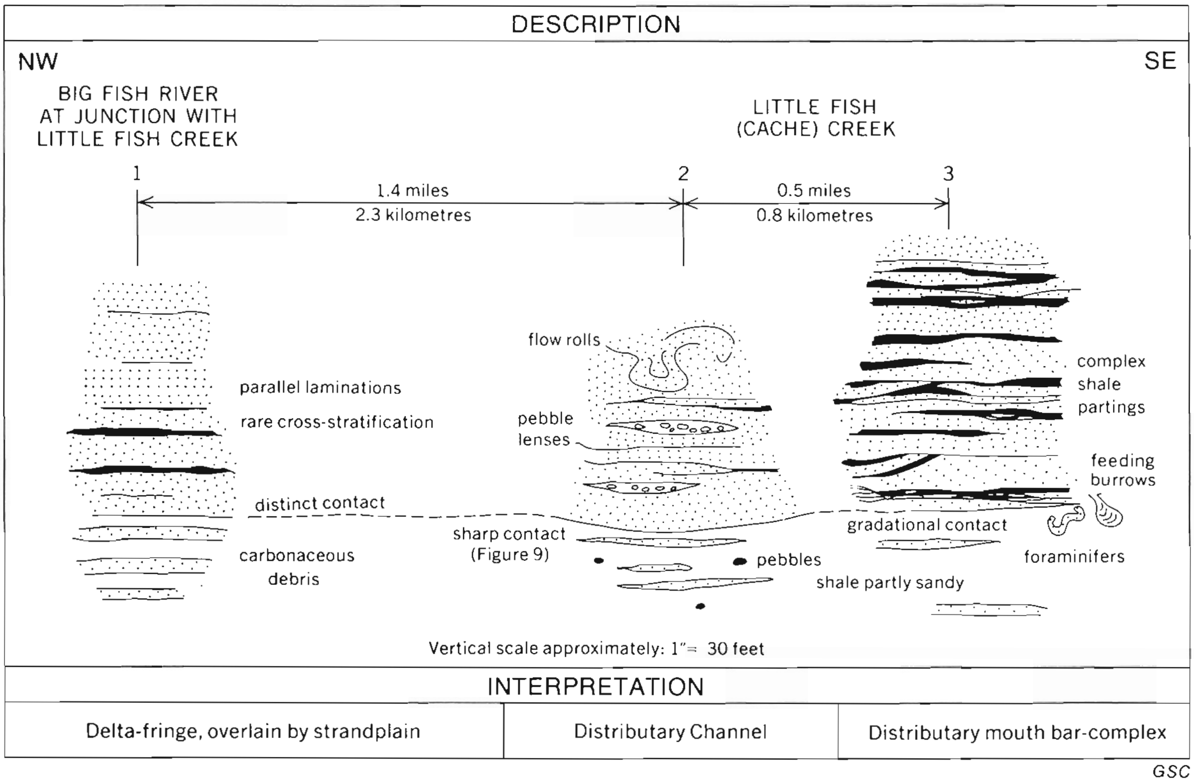

Figure 16. Comparison and interpretation of three closely spaced sections across Tent Island-Moose Channel contact, Big Fish River canyon

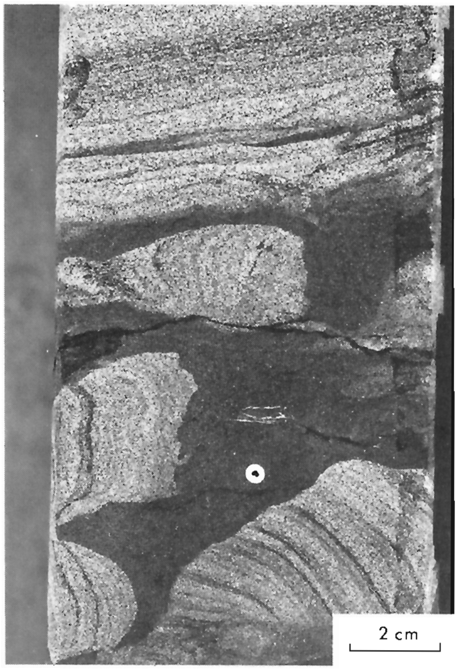

Figure 17. Convoluted and disjointed parts of laminated sandstone bed within mudstone, Moose Channel Formation; Core No. 9, depth 7,894 feet, I.O.E. Ellice 0-14 borehole. GSC 199055

Figure 18. Burrowed and bioturbated sandy mudstone, Moose Channel Formation; Core No. 9, depth 7,819 feet, I.O.E. Ellice 0-14 borehole. GSC 199056

the sandstone is more homogeneous and better sorted, suggesting a delta-fringe facies. The contacts of the Moose Channel sandstone units are sharp in the middle section (No. 2, Fig. 16) but become interfingering a short distance to the southeast. The sandstone in the middle section shows plane-laminations, low-angle cross-stratification, grain-size banding, large spherical flow-rolls, and conglomerate beds up to 1 foot (0.3 m) thick. This is interpreted as the axial part of a distributary channel where fluctuating bottom-currents existed. A short distance upstream on Little Fish (Cache) Creek, the contact becomes a complex array of intercalated irregular and lenticular shale and sandstone beds. The sandstone lenses exhibit large-scale tabular foresets, and contain foraging burrows of the *Teichichnus* and *Rhizocorallium* types. The shale contains sparse foraminifers (T.P. Chamney, pers. com.). The biogenic features indicate a shallow-marine environment (Howard, 1972) adjacent to the distributary mouth where sand-bars were intermittently established. At the northwestern section, the prodeltaic, very thin bedded carbonaceous muds grade upward into delta-front sand and shale containing abundant macerated carbonaceous debris. These beds grade upward into dominantly thick-bedded sandstone that shows plane-laminations, low-angle cross-stratification, and rare pebbly lenses, and generally is homogeneous and medium grained. This facies is thought to be the result of deposition in a marginal strand-plain and delta-fringe environment, influenced mainly by waves and wind-generated longshore currents.

Progradational cycles in the Ellice O-14 borehole consists of basal silty mudstone with carbonaceous and very fine sand laminae, grading upward into interbedded mudstone, siltstone, and medium-grained sandstone. Core No. 9 of the well penetrates this stage, and reveals convolutions (Fig. 17), graded beds, burrows, and bioturbated layers (Fig. 18) typical of a delta-front environment (Coleman and Gagliano, 1965). This gradational sequence is followed by well-sorted, medium-grained sandstone, probably of littoral origin. Capping each of the two cycles are thin beds of coal and silty mudstone which indicate lagoonal or marshy conditions. The submarine parts of these cycles were probably deltaic in origin, but were capped by barrier islands and strand-plains where coarse clastic sediments issuing from the distributary were reworked.

Littoral lithotope

This lithotope is present in small parts of all sections studied, and is best represented by a 500-foot (152 m) thick unit at the top of the basal member on lower Eagle Creek (Sec. 7). Its distinguishing features are: (i) dominance of uniform, well-sorted, fine- to medium-grained sandstone, and (ii) presence of foraging and feeding burrows. The latter are not common, but present throughout the member, and include a multiple type of *Rhizocorallium (?Gyrophyllites)*, and a type of *Asterosoma.*

Sedimentation structures include low-angle and high-angle tabular cross-stratification, in places with shallow basal scours, current lineations, plane-laminations with associated small shale-clasts, oscillation ripple-marks, and thin, pebble lenses and layers. Large coalified wood fragments and oxidized clayey-limonitic layers also are present. Cross-stratification dips (Fig. 30) indicate a dominant paleocurrent flow toward the east-southeast, but are widely dispersed, and show a weak bimodality.

The unit, containing alluvial sandstone tongues, is underlain by diverse, deltaic-plain deposits and overlain gradationally by coastal basin muds of the Ministicoog Member. These stratigraphic relationships and the associated structures and textures suggest deposition in a beach environment. Because there is no upward gradation from marine shale, these deposits probably were not of the barrier island type (Davies, Ethridge and Berg, 1971). Rather, the setting suggested is that of a beach-ridge strand-plain system, such as those described from the Rhone Delta (Oomkens, 1970) and the Senegal Delta (Wright and Coleman, 1972).

The amount and, in places, the thickness, of littoral sands in the basal member indicate that wave-power was nearly as important an influence on sedimentation as were fluvial currents. Hence, the morphology and distribution of sand-bodies of the delta system of the eastern basal sandstone member probably were similar to those of the modern Niger or Nile Deltas (Wright and Coleman, op. cit.), but on a smaller scale.

Ministicoog Member

The Ministicoog Member is characteristically a mudstone unit containing minor amounts of siltstone and sandstone but, in one section on Eagle Creek, the amount of sandstone occurring as interbeds increases to about one-half the volume of the rock. This interbedded sandstone and shale facies, as well as an associated sandstone facies, are described and interpreted below, and integrated with the interpretation and distribution of the mudstone facies in the chapter on Provenance and paleogeography.

Mudstone facies

At its type section on Big Fish River, the Ministicoog Member is dominantly brown-grey mudstone and shale, with varying amounts of siltstone (Fig. 10). The latter is thin to medium bedded, generally parallel-laminated or cross-laminated, and commonly occurs concentrated in thin beds intercalated with mudstone. The mudstone is generally soft and chunky-fracturing on weathered exposures, and is less commonly shaly or very thin bedded. Parts of the member contain abundant macerated carbonaceous debris. Three tongues of sandstone, all less than 100 feet (30 m) thick, appear in the member on Big Fish River. These sandstone bodies are fine- to coarse-grained chert litharenites, partly pebbly, and greatly resemble those of the basal sandstone member.

The Ministicoog retains the characteristics described above in cutbank exposures examined northwest of Big Fish River as far as the area of Coal Mine Lake. In the stream-cut section immediately southeast of Big Fish River, the siltstone interbeds grade toward very fine grained, slightly calcareous sandstone, with cross-stratification dipping at a small angle.

Figure 19. Interbedded sandstone and mudstone facies, considered to be tidal-flat deposits; Ministicoog Member, Moose Channel Formation; Eagle Creek. GSC 199052

At Deep Creek Syncline, about 50 miles (80 km) farther west, the recessive interval thought to represent the Ministicoog Member is covered largely and there are very few opportunities for examination. Only a few resistant units of sandstone and conglomerate outcrop and these appear to be markedly lenticular. These units display graded beds, large-scale tabular cross-stratification, and rounded cobbles of quartzite up to 20 centimetres across. Because these units apparently are enclosed within marine shale, they may represent some type of submarine channel or fan deposit. Most of the interval is probably mudstone, with minor beds of very fine grained sandstone and conglomerate occurring in its upper third.

In the I.O.E. Ellice O-14 borehole, the Ministicoog Member is dominantly greyish brown mudstone, in part silty, as at the type section. A few interbeds of siltstone and fine-grained sandstone are present, especially in the central part in the depth interval 6,000-6,170 feet (1830-1880 m). Parallel laminations, carbonaceous debris, and tiny burrows were observed in cuttings; the single core exhibits convolutions and bioturbation structures.

The large volume of mud and silt comprising this facies indicates a relatively quiet sedimentary environment, and its widespread distribution and preserved foraminifers strongly suggest a marine shelf environment. The abundance of macerated carbonaceous debris and the presence of burrows and rootlets suggest relatively shallow and nearshore settings in the case of the present coastal plain exposures. This is further supported by the apparent rapid lateral change to the interbedded sandstone and mudstone facies described next.

Interbedded sandstone and mudstone facies

The Ministicoog Member contains considerably more sandstone interbeds in exposures about four miles (6 km) above the mouth of Eagle Creek (Sec. 8) than at any other studied location. The trend, in this area, toward a sandstone facies in a southwesterly direction may explain why the basal sandstone member appears so thick in the bluffs immediately east of upper Eagle Creek.

The typical lithologic sequence at Eagle Creek consists of alternating resistant sandstone beds and recessive mudstone-rich intervals in about equal proportions (Fig. 19). The muddy intervals of this facies are recessive, yellow- and grey-banded, and contain thin, uneven lenses of semi-consolidated, medium- to coarse-grained sand; these have sharp basal contacts and graded upper contacts. Reed-like, carbonaceous plant fragments occur on bedding and parting surfaces. Current and oscillation ripple-marks, rootlets, and clay drapes or coatings are common in the upper parts of the sand interbeds. Burrows and load-casts are less commonly exposed on their under-surfaces.

The thick-bedded sandstone is fine to coarse grained, and pebbly, in common with the thin sandstone interbeds described above. In addition, it exhibits star-shaped feeding traces (*Asterosoma*), large coalified wood fragments, large convolutions, alternating fine- and coarse-grained bands, internal shaly intercalations with burrows, and streaky lamination.

The sand-rich units and thick sandstone beds are interpreted as having been deposited in the channels and as point bars of meandering tidal creeks (Van Straaten, 1961; Klein, 1967). The muddy intervals represent vertically accumulated sediments from the high tidal flats proper (Häntzschel, 1939), over which low sand bars and tributary creeks migrated, resulting in lenticular sandstone beds.

Present-day tidal flat sediments, or "tidalites" (Klein, 1971), in various parts of the world currently are being studied carefully by sedimentologists (R. Ginsburg, written com., 1972). Wünderlich (1970) compared the German Devonian "Nellenköpfchen beds" to the modern coastal environment of the German Bay, and illustrated interbedded coarse and fine clastic sediments on various scales ("tidal bedding") that are similar in form to those observed in the Ministicoog Member. Sedimentary structures associated with the German Devonian tidal sediments include horizontal and vertical burrows, trails, bioturbated layers, slumpings, oscillation and current ripple-marks, clay drapes on ripple-marks, dune cross-stratification, channel-fill beds, flaser and streaky lamination in mudstone, load casts, flute casts and others. Most of these structures were observed also in the interbedded sandstone-mudstone facies of the Ministicoog Member.

Sandstone facies

Near the base and the top of the above facies are two sandstone units, each 80 feet (24 m) thick, which are fairly uniform in character and consist mainly of well-sorted, fine- to medium-grained, and in part glauconitic sandstone. Because of their close stratigraphic relationship with the tidalites, their well-sorted nature, and the presence of glauconite, they are considered to have formed as baymouth bars or barrier island complexes.

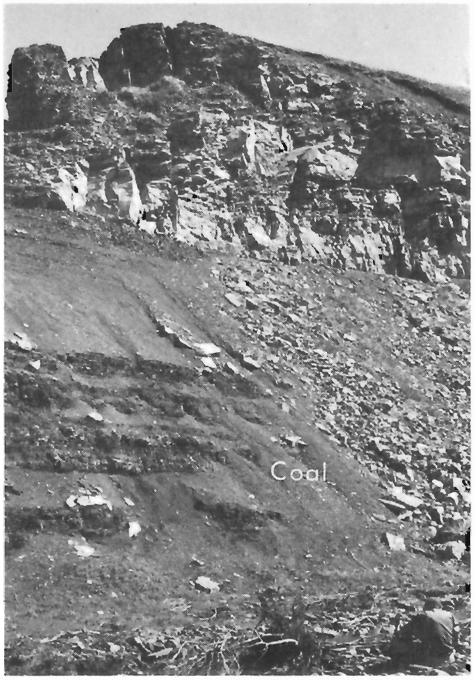

Figure 20. Vertical profile of coal, mudstone, conglomerate and sandstone in Aklak Member, Reindeer Formation; Aklak Creek. GSC 199067

Figure 22. Interfingering and graded beds of conglomerate and sandstone, Aklak Member, Reindeer Formation, Eagle Creek. GSC 199053

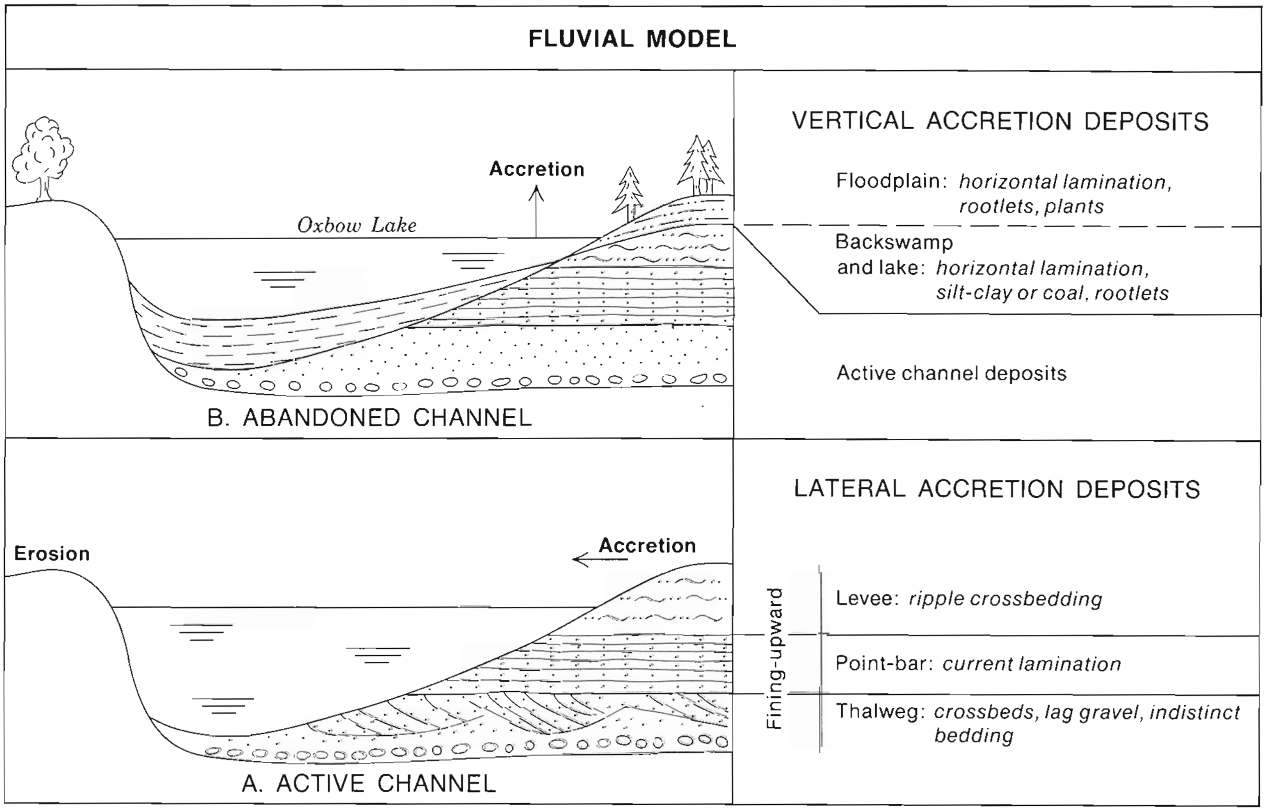

Figure 21. Fluvial models of sedimentation (after Visher, 1965b). A. Lateral accretion model. B. Vertical accretion model

REINDEER FORMATION

Aklak Member

The Aklak Member can be subdivided into three main lithofacies, including: (a) a sandstone-mudstone-coal facies, (b) a sandstone-conglomerate facies, and (c) a carbonaceous siltstone facies. The first facies is the most common, and comprises the basal half of the Aklak Member in the Ellice O-14 borehole. The second facies was recognized only at the base of the member on Eagle Creek, where it forms a resistant sandstone unit, 685 feet (205 m) thick. The carbonaceous siltstone facies is characteristic of the upper half of the member on Aklak Creek and in the Ellice O-14 borehole, and may constitute most of the recessive and covered interval above the resistant sandstone units on Eagle Creek.

The first two facies were discussed earlier under the heading Basal sandstone member, Moose Channel Formation in the secion describing the Alluvial lithotope, and only the important differences need be amplified here. One major difference is the more abundant coal and plant remains in the Aklak Member compared with the Moose Channel Formation. This may be due partly to a wetter climate which supported a more luxuriant flora at the time the higher unit was deposited. Similar trends have been noted elsewhere in North America in rocks of this sage (Rouse and Srivastava, 1972; Leffingwell, 1919). Also, the predominance of the delta-plain facies in the Aklak sections compared with the fluvial and littoral facies observed in the Moose Channel probably partly accounts for seemingly greater quantities of coal in the Aklak Member.

Sandstone-mudstone-coal facies

Vertical profiles of this facies show a typical upward succession of lithologies and structures (Fig. 20). At the base, in sharp contact with underlying mudstones, is pebble- to cobble-conglomerate, pebbly sandstone, or non-pebbly, fine- to medium-grained sandstone. Tabular cross-stratification and homogeneous beds occur in the basal part of the coarse clastic unit, and are succeeded by cross-lamination, ripple-marks and climbing ripples. In places, another set of tabular cross-stratified beds occurs at the top. This unit ranges greatly in thickness from a few feet to about 50 feet (15 m) from one cycle to the next. Commonly overlying the coarse clastic beds is a unit of coal and coaly mudstone, in units up to 20 feet (6 m) thick, which grade abruptly upward into coaly shale and, finally, silty, micaceous mudstone with abundant carbonaceous debris. The mudstone units are in part, or entirely, oxidized to red colours with associated ancient bocanne (cinder and clinker beds).

The coarse clastic phases of these cycles probably represent fluvial channel and point bar deposits (Visher, 1965b) (Fig. 21, A). Wherever these are terminated abruptly at the top and overlain by coaly sediments, the process of channel avulsion may have occurred with the attendant abrupt change from high-energy to low-energy sedimentation (Fig. 21, B). As the meander loops and swales were filled with organic muck they tended to merge with the surrounding backswamp or floodplain, and fine clastic sediments gradually replaced the organic sediments in the upper parts of the cycles. Alluvial cycles with a high proportion of overbank deposits have been described from a variety of ancient complexes (Allen, 1965), and have been interpreted (Allen and Friend, 1968; Beerbower, 1964) as having been formed by meandering streams in well-cut channels whose sediment load was dominantly silt and clay.

Sandstone-conglomerate facies

This is essentially the same facies as the "coarse sandstone facies" of the basal sandstone member, except that the Aklak representative consists mainly of fine-grained sandstone and contains thicker conglomerate units than the basal member. Similarities in sedimentary structures include conglomerate-filled scours, coarse sand- and pebble-lenses (Fig. 22), and cross-stratification. Therefore, as in the case of the coarse sandstone facies, this sandstone-conglomerate facies is considered to result from deposition by braided streams.

Carbonaceous siltstone facies

Approximately 600 feet above the base of the section on Aklak Creek is an interval, at least 250 feet (76 m) thick, consisting of relatively uniform, poorly exposed, red-weathering siltstone and silty mudstone. In the middle of this unit is a thin sequence consisting of 2 feet (0.6 m) of fine-grained sandstone at the base, overlain by 2 feet (0.6 m) of unconsolidated seat-earth and capped by 0.5 feet (15 cm) of friable coal. Scoria-like ancient bocanne appears in slope debris throughout the unit. Orange-weathering limestone, silty and micritic, occurs rarely at the top of the unit. Rootlets are common in the siltstone, and faint leaf impressions are rare.

Other similar thick siltstone and mudstone units occur in the top of the Aklak at the type section, and can be assigned reasonably to the same depositional setting. The redness, due to the presence of oxidized ferruginous minerals, is probably the result of chemical changes associated with spontaneous combustion and weathering, because many samples are internally grey when freshly broken.

Although it lacks any ancient bocannes as would be expected in a deeply buried subsurface section, the depth-interval 3,900-4,500 feet (1190-1370 m) in the Ellice O-14 borehole consists of siltstone, bituminous shale, fine-grained argillaceous sandstone, and coal, similar to the surface sections. In both sections these lithologic types overlie the alluvial sandstone-mudstone-coal facies.

The carbonaceous siltstone facies, with its evidence of quiet sedimentary conditions and subaerial vegetation, is characteristic of the delta-plain, in which swamps, lakes, crevasse-splays, levees, and coastal embayment form an interwoven complex. This facies and its electric log expression in the Ellice O-14 borehole are strikingly similar to the delta-plain facies described by Fisher (1969) from the Lower Wilcox Group of the Gulf Coast. He attributed thick accumulations of this facies to high constructive deltas, in which

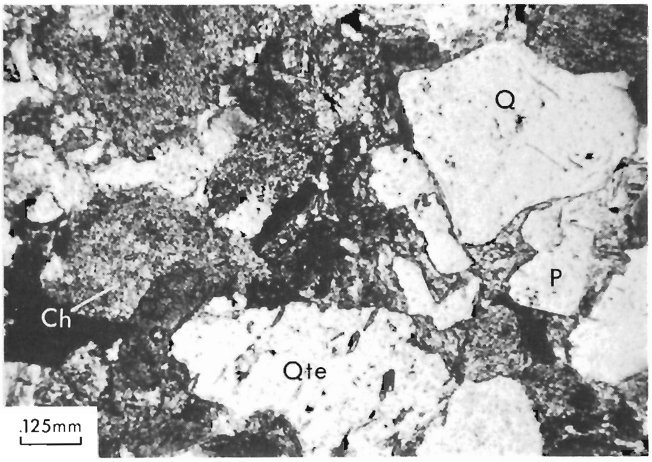

Figure 23. Photomicrograph of sandstone from basal Moose Channel Formation, Eagle Creek; Sample 122 YA-4, ordinary light. Quartz (Q), quartzite (Qte), plagioclase (P), chert (Ch). GSC 199058

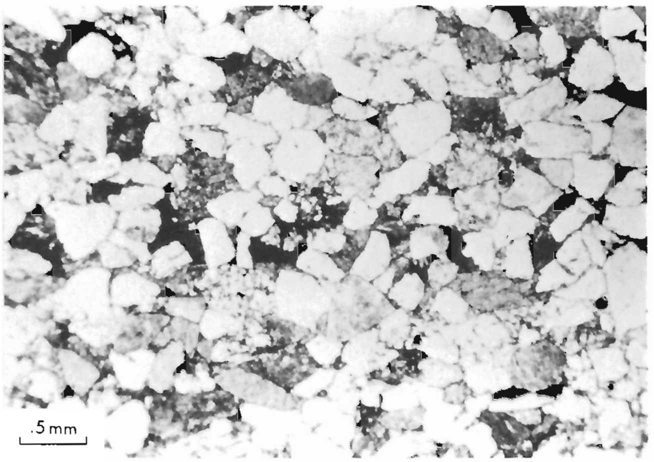

Figure 25. Photomicrograph of sandstone from top of Ministicoog Member, Moose Channel Formation, Eagle Creek; Sample 143 YA-6; ordinary light. GSC 199059

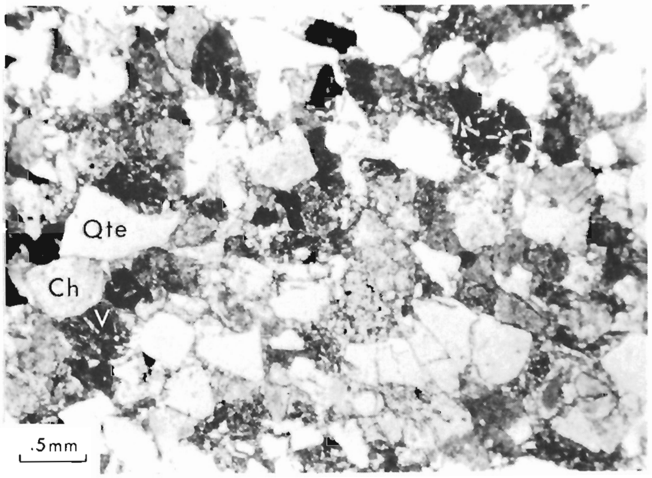

Figure 24. Photomicrograph of sandstone from basal Moose Channel Formation, Deep Creek area; Sample 31f YAb-1; ordinary light; grains consist of quartz, quartzite (Qte), chert (Ch), and volcanics (V). GSC 199060

fluvial forces and their resulting deposits far exceed those of marine influence.

SANDSTONE PETROGRAPHY
(Fish River Group and Reindeer Formation)

Sandstones of the Fish River Group and Reindeer Formation display a general similarity in textures and compositions, and can be classified as immature, chert litharenites (Folk, 1968). In this study, emphasis was placed on defining compositional trends, both in stratigraphic and in an areal sense, in the hope that members could be differentiated on the basis of sandstone composition. This undertaking met with limited success and is discussed below. Modal analyses were performed on 33 thin sections; over 500 points were counted per section (Griffiths, 1967, p. 191), and the results are summarized on Table 3.

Holmes and Oliver (1973) performed an independent petrographic analysis of these rocks and reported similar findings. The reader is urged to compare the results and interpretations of these two studies in order to benefit from different perspectives.

TEXTURES

Textural characteristics, common to nearly all sandstones sampled, include angularity of arenaceous particles, and very tight packing (Figs. 23-25). The sandstone units display a complete range of modal grain-sizes, varying from silt to pebble size, as visually estimated. Fine- to coarse-grained sandstone probably is most common, whereas very coarse grained sandstone and granular conglomerate (1 to 4 mm) are the least common.

Non-particulate components

Interstitial matrix comprises only a minor part of these sandstones, but is less than 5 per cent of the rock in only 1/4 of the samples analysed. Some of the matrix, however, probably comprises crushed labile particles and diagenetic precipitates. Hence the amount of original detrital matrix is probably somewhat less than that measured. The average matrix content of all samples is 10 per cent; that of the seven samples from the Ellice O-14 borehole is 14.9 per cent.

The matrix generally consists of admixtures of clay, sericite and quartz. Bituminous matter comprises the matrix of some alluvial sandstones.

Interstitial pores occur in many sandstones in which secondary cements are lacking, but this porosity may be due, in part, to leaching of calcite at the outcrop. Patchy calcite cement is present in many samples from all parts of the group and from all areas studied. Also, quartz overgrowth cement commonly is present in small amounts, even in samples containing calcite pore-fillings.

Rounding

The small amount of rounding of sand-size particles is a striking feature of these sandstones (Fig. 24). Quartz and chert grains up to 1 millimetre in greatest diameter are mostly subangular (Powers, 1953), with angular and subrounded grains less abundant. Visual estimates indicate that sandstone from the Big Fish River area displays greater angularity than that of the Deep Creek area. In all formations studied, particles greater than 2 millimetres in diameter are subrounded to well rounded. Such particles tend to be dominantly chert, showing that "maturity" in texture and durability is attained much faster in rudaceous populations than in arenaceous ones (Pettijohn, 1957).

Grain sizes and sorting

No formal size analyses were performed on thin sections or disaggregated rock samples. From measurements of projected grain diameters viewed through a petrographic microscope and estimating the ranges of sizes within individual thin sections (Folk, 1968), it is evident that most of the sandstone samples examined are composed of moderately well sorted grains. Many examples of poorly sorted and well-sorted sandstone also are present.

Packing

Sandstone units of the Fish River Group typically are greatly compacted (Fig. 23) and display fabrics which attest to high post-depositional pressures. The most notable evidence of considerable compaction is the overly close grain-to-grain relationship which in most sand grains touch neighbouring grains along straight contacts (Griffiths, 1967) in thin section (Fig. 25). Embayed or sutured contacts are present in samples from the Ellice O-14 borehole as well as from surface material. The suturing probably was aided by the process of pressure solution (Thomson, 1959) which, in turn, provided silica for cement as continuous overgrowths and microcrystalline pore-fillings in areas of lesser pressure.

Bent, twisted and crushed grains of muscovite, phyllite, microschist, limestone and carbonaceous flakes also bear evidence of high compacting pressures. Many long, grain-to-grain contacts were achieved by the physical deformation of relatively soft granular materials.

The large compressional forces which caused these compactional textures may have been either tectonic or geostatic in origin, or possibly both.

COMPOSITION

Quartz and chert, as well as metamorphic, sedimentary, and volcanic rock fragments, are the main constituents of the Fish River Group and Reindeer sandstone units, in their order of decreasing abundance. Variations in the relative amounts of each constituent were found to exist between certain outcrop areas, and between the different formations. These variations reflect the localized nature of the source-areas of this detrital material, which would result from the drainage of a heterogeneous upland by relatively short streams.

Types of particles

Quartz

Quartz is the most abundant component (average portion of particulate fraction is 42%) of the sandstones, and consists mainly of ordinary plutonic and vein quartz. Polycrystalline quartz from metaquartzite and recrystallized chert also is common. Volcanic quartz was not recognized, despite the abundance of volcanic rock fragments.

Chert

Many varieties of chert were deposited in these sandstones, including the following main types:

(i) colourless, microcrystalline quartz (<20 microns);

(ii) brown, nearly opaque, (?)phosphatic chert;

(iii) pale brown, chalcedonic, nearly isotropic chert; and

(iv) spherulitic (radiolarian?) chert.

All gradations of chert to argillite, or chert to altered tuff are present; hence, chert is placed here with lithic components for classification purposes (Folk, 1968; Chen, 1968) instead of with the quartz fraction.

Sedimentary and metamorphic rock fragments

Large amounts of slate, phyllite, and quartz-mica schist are present in the sandstones; the conglomerates commonly contain phenoclasts of very fine grained siliceous sandstone, in part chert-bearing. Locally, there are enrichments of crystalline limestone fragments (usually single detrital crystals) and bituminous slate or microschist.

Igneous rock fragments

Fragments of plutonic igneous rocks are exceptional; only the rare granitoid fragment was recognized. However, extrusive igneous rock detritus generally is common in surface samples, and includes fragments of spilitic and andesitic basalts and various kinds of tuff. Volcanic fragments are absent to rare in the Blow River E-47 and Reindeer D-27 boreholes.

Strat. Unit		Field No.	Est'd mean† grn-size	Particulates (recalculated to 100%)								Matrix			Ratios			
				% Vol.	Qtz	Cht	Lith	Volc	K-Fp	Plag	Oth	Void	Cem	Det	Qtz/Cht	Fsp/RF	V & P	V&P/Cht
TENT ISLAND FM	Cuesta Creek Mbr.	58 YA-3	mg	83	33	57	10	-	tr	-	tr	-	12	6	0.6	0	0	0
		21 YAb-15	mg	77	47	23	23	2	1	1	4	2	6	14	2.0	0.03	2	0.09
		196 YA-5	cg	85	30	22	13	15	6	4	11	-	8	7	1.4	0.19	18	0.62
		33c YAb-4	mg	79	46	31	15	1	1	2	5	19	-	2	1.5	0.08	3	0.10
		E-47-5	mg	84	31	31	30	-	1	1	4	-	12	5	1.0	0.04	1	0.03
		MEAN VALUES			37	33	18	4	2	2	5				1.3	0.07	5	0.17
		STANDARD DEVIATIONS			7.5	11.8	8.2	5.7	2.1	1.4	3.5				0.55	0.07	6.7	0.26
MOOSE CHANNEL FORMATION	Basal Sandstone Member	34 YA-6	fg	61	32	21	15	9	7	5	10	11	6	22	2.1	0.30	15	0.71
		35 YA-2	mg	79	35	20	2	29	2	9	3	14	1	6	2.0	0.22	38	1.90
		37 YA-1	fg	71	56	13	12	7	6	4	3	24	-	5	4.3	0.33	11	0.85
		38 YA-3	mg	78	51	15	11	7	6	8	3	7	9	7	3.5	0.41	15	1.0
		40 YA-3	fg	85	44	15	16	9	4	6	7	8	-	7	2.9	0.25	15	0.94
		124b YA-1	fg	80	37	16	11	8	3	14	12	-	4	16	2.3	0.48	22	1.37
		122 YA-8	mg	84	32	27	8	14	4	11	4	6	1	9	1.2	0.29	25	0.93
		2 YA-1	fg	71	60	25	2	-	8	tr	5	18	6	5	2.4	0.28	tr	0
		E-47-1	fg	72	45	23	25	-	3	2	3	-	16	12	2.0	0.10	2	0.09
		0-14-11	fg	82	41	22	20	5	4	2	6	3	-	16	1.9	0.14	7	0.32
		0-14-20	mg	75	46	26	14	2	5	5	2	-	-	24	1.8	0.25	8	0.31
		0-14-21	mg	74	44	22	20	6	3	4	3	1	4	21	2.0	0.15	10	0.46
		0-14-27	fg	78	54	25	8	3	3	2	4	-	5	16	2.2	0.16	5	0.20
		D-27-26	fg	73	42	20	18	tr	4	4	12	-	4	23	2.1	0.18	8	0.40
		D-27-34	mg	68	29	24	23	1	2	5	16	-	1	31	1.2	0.14	6	0.40
		MEAN VALUES			43	21	14	7	4	5	6				2.3	0.25	12	0.70
		STANDARD DEVIATIONS			9.0	4.2	6.7	7.2	1.7	3.6	4.2				0.77	0.10	9.5	0.50

Strat. Unit		Field No.	Est'd mean† grn-size	Particulates (recalculated to 100%)								Matrix			Ratios			
				% Vol	Qtz	Cht	Lith	Volc	K-Fp	Plag	Oth	Void	Cem	Det	Qtz/Cht	Fsp/RF	V & P	V&P/Cht
MOOSE CHANNEL FORMATION	Ministicoog Mbr.	42 YA-4	mg	92	45	18	24	5	4	1	3	3	1	4	2.5	0.11	6	0.32
		10 YAb-6	fg	87	54	10	15	1	3	4	14	2	tr	11	5.5	0.22	4	0.40
		143 YA-6	mg	83	43	25	13	7	2	12	3	-	-	17	1.7	0.32	20	0.80
		140 YA-11	mg	84	35	20	10	14	2	17	3	5	7	4	1.7	0.44	31	1.55
		0-14-9	fg	87	42	26	22	-	2	1	7	-	-	13	1.6	0.06	2	0.08
		MEAN VALUES			44	20	17	5	3	7	6				2.6	0.23	13	0.63
		STANDARD DEVIATIONS			6.2	5.7	5.6	5.0	1.2	6.4	4.2				1.5	0.14	11.2	0.58
REINDEER FM	Aklak Member	30f YAb-1	fg	81*	61	26	8	1	1	2	1	(15)	12	8	2.4	0.11	3	0.12
		169b YA-1	mg	97*	39	48	9	1	1	-	2	(34)	2	2	0.8	0.03	1	0.03
		13 YAb-5	fg	92	30	35	19	1	3	1	11	3	-	6	0.8	0.09	2	0.06
		33a YAb-10	mg	77	50	24	10	3	4	5	5	-	13	10	2.1	0.24	7	0.29
		0-14-4	mg	85	35	46	8	7	3	tr	2	9	4	2	0.8	0.06	7	0.15
		0-14-7	fg	88*	38	24	19	8	3	2	6	(14)	-	12	1.6	0.09	10	0.42
		MEAN VALUES			42	34	12	4	3	2	4				1.4	0.10	5	0.18
		STANDARD DEVIATIONS			11.0	11.0	5.1	2.9	1.1	1.7	1.7				0.66	0.07	3.2	0.15

GSC

% Vol - percentage volume occupied by particulates
Qtz - quartz
Cht - chert
Lith - lithic fragments
K-Fp - potash feldspar
Plag - plagioclase feldspar

Cem - cement
Det - detrital matrix
Fsp/RF - feldspar/rock fragments (incl. chert)
V & P - volcanics and plagioclase
† - Wentworth grade scale
( ) - void due to plucking during slide preparation
* - plucked material ignored

TABLE 3. Compositional Analyses of Fish River Group Sandstones

Feldspars

Feldspar grains consist of potash feldspar and plagioclase. The potash feldspar is predominantly orthoclase or sanidine; microcline and perthite are very rare. Plagioclase occurs mainly as angular, fresh, arenaceous grains, and commonly shows polysynthetic twinning. Measurements of extinction angles of paired twins by the Michel-Levy technique indicate compositions within the range An_{20-30} (andesine). Lesser amounts of untwinned plagioclase containing vacuoles are present. The amount of potash feldspar in these sandstones is relatively constant (average 4%), but the amount of plagioclase varies greatly, generally in direct proportion to the abundance of volcanic detritus.

Variations in sandstone composition

Compositional analyses by point-counting thin sections of sandstone were made in order to determine compositional characteristics of the various members at different localities. Only fine- and medium-grained sandstone units were analysed because coarser varieties tend to be enriched in chert and lithic fragments, and finer ones enriched in quartz. The analysed proportions of each component are given in Table 3 according to the member from which the samples were derived. Only samples from the base (Cuesta Creek Member) of the Tent Island Formation were analysed, because higher in the formation sandstone generally is lacking.

Differences in amounts of the main constituents of sandstone among the formations are subtle, and these also vary according to locality. Although a given formation may display considerable variation in composition from place to place, compositional changes from the base to the top of the sequence tend to be similar in all localities. Also, certain accessory materials, such as detrital carbonate, appear in limited parts of the section. These trends are useful in identifying stratigraphic units in the subsurface where fossil control is imprecise or unavailable.

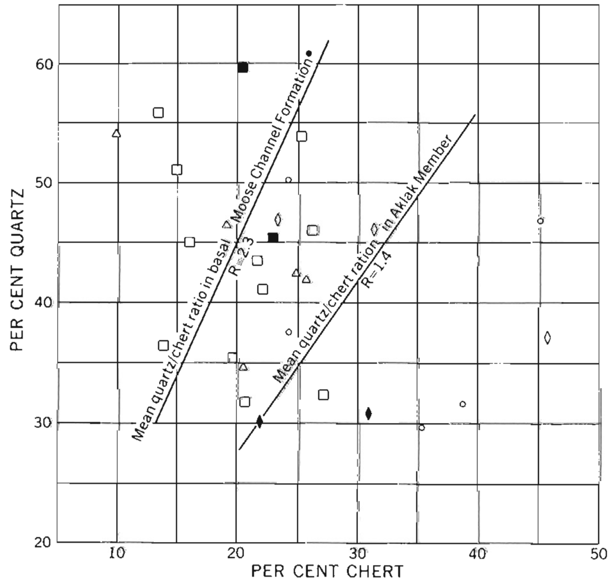

Figure 26. Diagram showing quartz versus chert contents, Fish River Group and Reindeer Formation sandstones

Quartz, potassium feldspar, and sedimentary plus metamorphic rock fragments display relatively constant proportions in sandstones throughout the succession. The average amount of quartz in the particulate fraction is 42 per cent, of potassium feldspar 3 per cent, and of rock fragments 15 per cent. The particle types exhibiting variable proportions among the several stratigraphic members are chert, volcanic rock fragments, and plagioclase. These components, therefore, are the most useful in differentiating stratigraphic units and studying areal composition trends.

Chert is most abundant in the Cuesta Creek sandstone units, where it averages 34 per cent. It is considerably less abundant in the basal sandstone and Ministicoog members of the overlying Moose Channel Formation, where it averages 21 and 20 per cent respectively. It is more abundant, however, in the younger Aklak regressive phase, where it averages 34 per cent in six samples. Because of the relatively constant amount of quartz, the quartz/chert ratio varies mainly due to changes in chert content. The ratio averages 1.3 in the Cuesta Creek Member, rises to 2.3 and 2.6 in the Moose Channel Formation, then falls back to an average of 1.4 in the Aklak Member (Fig. 26). This trend is far more pronounced in individual sections, such as at Aklak Creek, where the quartz/chert ratio increases to a maximum of 5.5 toward the top of the Ministicoog Member, then decreases sharply in the overlying Aklak Member to 0.8.

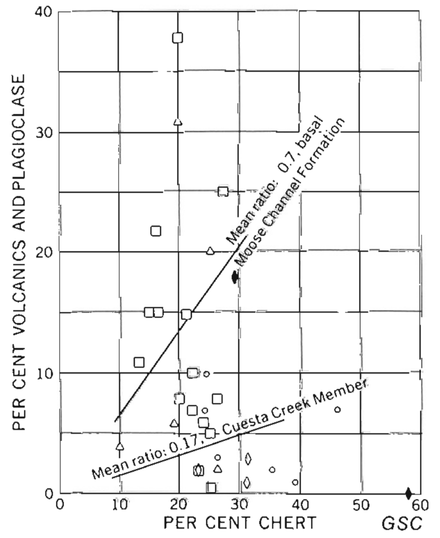

Figure 27. Diagram showing volcanics plus plagioclase versus chert contents, Fish River Group and Reindeer Formation sandstones

West East
● .... *Aklak Member, Reindeer Formation* .... ○
Ministicoog Member, Moose Channel Formation .... △

West East
■ .... *Basal sandstone member, Moose Channel Formation* .... □
⧫ .... *Cuesta Creek Member, Tent Island Formation* .... ◊

The abundance of plagioclase approximately varies inversely to the chert content from one member to the next. In the Cuesta Creek Member, for example, where chert is relatively abundant, plagioclase is relatively rare (average amount is 2%). In the eastern outcrop area the Cuesta Creek Member is depleted in both types of feldspar (average total feldspar content is 1.6%). Feldspars, and in particular plagioclase, increase to a maximum proportion in the Moose Channel Formation. In the Aklak Member of the Reindeer Formation, it is a very minor component (average amount is 2%), as it is in the Cuesta Creek Member of the Tent Island Formation.

The amount of volcanic rock fragments varies in a similar way to that of plagioclase, suggesting that either the two were derived from common sources, or they were degraded during sediment transport in similar ways. Volcanic detritus is least abundant in the Cuesta Creek Member, except for its occurrences in the western coastal plain, and most abundant in the basal sandstone member of the Moose Channel Formation (average amount is 7%).

Because of their inverse relationship, the proportions of volcanic rock fragments plus plagioclase (V + P in Table 3) versus those of chert can be used to enhance petrographic differences and trends among the various sandstone members (Fig. 27). The average age value of the ratio V + P/chert is 0.17 in samples of the Cuesta Creek Member, 0.70 in the Moose Channel, and only 0.18 in the Aklak Member. The t-statistic, which compares the means and standard deviations of two separate sample-groups and tests them for equality, was applied to ratio-values of the Aklak Member versus those of the lower Moose Channel. The test indicates that real differences in the values of this ratio indeed exist at the 95 per cent confidence level.

Notable variations of a given component also occur among different sections or localities. These variations also are dominant among chert, plagioclase, and volcanic rock fragments (Table 4). The combined amounts of volcanic fragments plus plagioclase in sandstone of the Eagle Creek area are about twice as great as those of the Big Fish River area, and three times greater than those in the Moose Channel and Reindeer of the Ellice 0-14 borehole. These marked areal differences in composition must be a result partly of local derivation of clastic materials.

Summary

Tent Island Formation, Cuesta Creek Member

(i) high chert content; over-all average, 34 per cent.

(ii) very low feldspar content in eastern outcrop area; average, 26 per cent.

(iii) very rare volcanic rock fragments in eastern area (<2%), but common in Deep Creek area (15%).

(iv) low values for ratios of quartz/chert, 1.3; feldspar/rock fragments, 0.07; and V + P/chert, 0.17.

Moose Channel Formation

Basal sandstone member

(i) low chert content; over-all average, 21 per cent.

(ii) high feldspar content (general <5%), plagioclase particularly enriched (average: 5%).

(iii) high volcanic rock fragments content; over-all average, 7 per cent.

(iv) high values for ratios of quartz/chert, 2.3; feldspar/rock fragments, 0.25; and V + P/chert, 0.70.

Ministicoog Member

(i) similar petrographic characteristics to basal sandstone member; feldspar generally less abundant.

(ii) presence of small amount of clastic carbonate a characteristic in eastern area and I.O.E. Ellice 0-14 borehole.

Reindeer Formation

Aklak Member

(i) high chert content; over-all average, 34 per cent.

(ii) very small plagioclase content (generally 2% or less).

(iii) low values of ratios, but not so low as those of Cuesta Creek Member; quartz/chert, 1.4; feldspar/rock fragments, 0.10; V + P/chert, 0.18.

STRATIGRAPHIC CORRELATIONS

LOCAL CORRELATIONS

Due to a lack of regional marker beds and the localized nature of deltaic sedimentation, lithostratigraphic correlations of surface and subsurface sections are difficult. Paleontological control is

Area	Deep Creek	Eagle Creek	Big Fish River	IOE Ellice 0-14
No. of samples	2	5	9	7
Chert	25	22	21	27
Volcanic RF's	1	9	8	4
Plagioclase	1	12	4	2
Volc. & Plagio.	2	21	12	7

GSC

Table 4. Areal compositional differences in Moose Channel Formation sandstones

restricted to various microfossil groups and plant fossils, which are confined to the upper part of the group. Many of the correlations presented here (Fig. 28) are tentative and subject to revision as more detailed micropaleontological studies are made and their results brought to bear on the problem.

The types of data used to make the correlations include, in the approximate order to decreasing reliability:

(i) similar fossil assemblages and diagnostic species;

(ii) lithologic markers and petrographic peculiarities in association with homotaxial stratigraphic sequences; and

(iii) geological age assignment based on different fossil groups.

Much reliance is placed on the concept that the thick marine shale formations represent regional transgressions which are generally contemporaneous over large areas, and that thick, coarse, alluvial units represent intervals when debris was being shed over large areas from upland sources. Hence, the homotaxiality of stratigraphic sequences is regarded as a reasonable first approximation for gross correlations, and becomes increasingly reliable as more independent paleontological support is obtained.

Big Fish River area to Eagle Creek area

From the type section on Big Fish River to nearby creeks to the southeast and northwest, correlations can be made by almost direct tracing of markers and larger stratigraphic units. The Eagle Creek section, which is in a different structural element from the above, contains faults and is pieced together and correlated with the type section on the basis of thickness and lithologic similarities of individual formations and fossil assemblages.

Type area to the I.O.E. Blow River YT E-47 borehole

The Upper Cretaceous age of the uppermost 4,000 feet (1220 m) of the I.O.E. Blow River YT E-47 borehole was not recognized until comparatively recently, when T.P. Chamney examined foraminiferal remains from well-cuttings over this interval. There are no hints of such an age from the poorly exposed surface geology near the wellsite, which is located within a wide belt of deformed, upper Lower Cretaceous, pelitic sediments. Samples from the depth-interval 1,700 to 1,800 feet (518-548 m) contain microfossils typical of the "*Cyclammina*" sp. 1A assemblage zone which occurs in the Tent Island Formation. The sandstones present above a depth of 1,350 feet (412 m) are probably Moose Channel Formation, and those from about 3,100 to 3,370 feet (940-1030 m) belong to the Cuesta Creek Member. The shales immediately below but above the angular discontinuity (as established from dipmeter logs) at 3,990 feet (1220 m), are assigned tentatively to the Boundary Creek Formation. Microfaunal remains below this horizon, which is thought to be an angular unconformity, suggest an Early Cretaceous, mainly Albian age.

Type area to Deep Creek area

The correlation of the members present in the Deep Creek area with those of the type Fish River Group are tentative, being based primarily on the homotaxiality of the two successions. The two outcrop areas are discontinuous, and separated by a north-trending zone of deformed Lower Cretaceous shale. In both areas, the group has a fluviatile conglomerate and coarse sandstone unit (Cuesta Creek Member) at its base, characteristically preserved only locally, and is overlain by a thick mudstone unit identified in both areas as the Tent Island Formation. It seems to be considerably thicker in the western outcrop area, where Foraminifera appear to be Senonian in age (Chamney, internal report on collections by D.K. Norris). Hence, the basal conglomerate may be older in the Deep Creek area and may be of quite different ages from one occurrence to the next.

A dominantly sandstone formation occurs above the Tent Island Formation, homotaxial with the basal member of the Moose Channel Formation. An intermediate mudstone unit is similar in lithology and thickness to the Ministicoog Member on Big Fish River, and is overlain by another sandstone unit tentatively correlated with the Aklak Member. Coaly material collected by D.K. Norris from an outcrop believed to be near the contact of the two upper units yielded pollen of Maastrichtian or possibly Paleocene age (Brideaux, Paleont. Rept. K6-WWB-1971), which agrees with palynological datings of rocks near this contact in the type area.

Type area to I.O.E. Ellice O-14 borehole

The Aklak Member is correlated between the type area and the I.O.E. Ellice O-14 borehole with greater confidence than is the Moose Channel Formation. The Aklak Member consists of similar nonmarine rocks in both sections and, according to Brideaux (Paleont. Rept. WWB-2-1972), contains nearly identical pollen assemblages (cf. GSC loc. C-11299 with C-12661). The underlying Ministicoog mudstone is similar in thickness and lithology in both sections, and contains sandstone with small amounts of carbonate detritus. The basal member of the Moose Channel Formation is much shalier in the Ellice O-14 well than at the type section, but contains sandstone with relatively large amounts of feldspar as at the type section. The probable basal contact with the Tent Island Formation is gradational because of a coarsening-upward sequence similar to that observed at the type section (Fig. 16). This cycle, however, may be underlain by more cycles with sufficient arenaceous beds to justify placement in the Moose Channel Formation.

Type area and Ellice well to Reindeer D-27 borehole

Because the biostratigraphy of the B.A.-Shell-I.O.E. Reindeer D-27 borehole has been published

(Chamney, 1971, 1973), it seems appropriate to attempt to relate that work to the present study. The correlations presented in Figure 28 are based on the similarities of microfaunal assemblages between the Reindeer D-27 well and surface sections of the type area of the Fish River Group, especially at the level of the Tent Island Formation. Chamney (1972) reported that his "*Cyclammina*" sp. 1A foraminiferal assemblage zone (Division 11) of the Reindeer D-27 borehole occurs in the lower condensed section on Little Fish (Cache) Creek. Ages assigned by Chamney to the overlying divisions from the Tent Island Formation up to a depth of 4,740 feet (1448 m) in the Reindeer D-27 well, where he depicts a major unconformity, correspond with those of the type Moose Channel Formation. In this study, the unconformity is placed lower in the section at a depth of 4,990 feet (1522 m), on the basis of dipmeter logs which show an abrupt change in bedding attitude at this level. A conglomeratic unit occurs directly above this discontinuity, lending support to the concept of an angular unconformity, and agreeing in lithologic character with deposits above this level. Above the unconformity, the poorly dated conglomerate and sandstone are apparently younger than the type Aklak Member, and probably are correlative with the Reindeer Formation of the nearby Caribou Hills, which contains a Paleocene microflora (Brideaux, Paleont. Rept. K5-WWB-1972).

A discrepancy exists in age assignments in the lower half of the Reindeer D-27 borehole (various pers. coms.) based on micropaleontological research by various workers. Considerably younger ages are attributed by some to the thick shale formation in the interval between 7,000 and 11,000 feet (2140-3360 m) as evidenced by the published work on Foraminifera by Petracca (1972) and Langhus and Petracca (1973). They assigned an Eocene to Oligocene age to cuttings from depths between 9,000 and 10,000 feet (2750-3050 m) and core-samples between 9,573 and 9,598 feet (2920-2930 m). This discrepancy is discussed by Chamney (1973b, p. 177), and until such time as these differences have been resolved, the correlations shown here (Fig. 28) are based on Chamney's extensive micropaleontological work on the Reindeer D-27 well and the consistent lithostratigraphic framework which supports these correlations.

REGIONAL CORRELATIONS

Correlations of Late Cretaceous and Early Tertiary stratigraphic units in northern Yukon Territory and northwestern District of Mackenzie were discussed by Mountjoy (1967a), and were slightly modified and tabulated in "Geology and Economic Minerals of Canada" (Douglas, 1970, Chart III). Jeletzky (1971a, 1972) summarized the regional correlations and paleobiogeography of Cretaceous rocks for this and surrounding areas. Further modifications to some of these correlations are necessary in the light of recent paleontological research (Table 5) and are discussed below according to geologic province.

North-central Yukon Territory

In Eagle Plain, the lower shale member of the Eagle Plain Formation ranges in age up into the Campanian Stage according to Chamney (1971b) who examined microfauna in cuttings from the Socony Mob.-West. Min. Molar YT P-34 borehole. Hence the formation is correlative with the Tent Island Formation of the Fish River Group. To the west of the Molar P-34 well, at least 2,500 feet (760 m) of sandstone and shale of the Eagle Plain Formation lie above the spud-in stratigraphic level of the well. Therefore, this part of the formation may be as young as Maastrichtian and is equivalent to the Moose Channel Formation.

The lower part of the Eagle Plain Formation has yielded Cenomanian Foraminifera (Chamney, op. cit.), the Cenomanian *Inoceramus* ex gr. *dunveganensis* McLearn (Mountjoy, 1967a), and Turonian to Coniacian pelecypods *I.* ex aff. *cordiformis* Sowerby and *I.* ex gr. *deformis* Meek (Jeletzky, 1973), and thus is correlative with the Boundary Creek Formation. Equivalents of the Boundary Creek Formation (Turonian to Santonian marine shale and sandstone) also occur on Porcupine River between the mouth of Driftwood River and Old Crow village (Jeletzky, 1972).

Southwest of Eagle Plain in western Ogilvie Mountains is the Monster Formation which was assigned a late Late Cretaceous age by Mountjoy (1967a) on the basis of leaf fossils identified by W.A. Bell. Green (1972) described a new section of this unit and submitted new fossil plant collections to F.M. Hueber for identification, but Hueber was unable to date these with any greater precision. The writer has measured two sections of this formation and submitted material to W.W. Brideaux for palynological analysis, but the samples proved to be barren. Hence the Monster Formation, and similar strata westward in Alaska (Mertie, 1937), generally are equivalent in age to the Fish River Group and the upper part of the Eagle Plain Formation.

The Bonnet Plume Formation of Bonnet Plume Basin was the subject of detailed palynological research by Rouse and Srivastava (1972), who documented the Maastrichtian to Paleocene age of this largely nonmarine formation. Their paleoecological interpretations and regional correlations are relevant to the correlative Fish River Group.

Norman Well-Great Bear Plain areas

The Cretaceous stratigraphy of the Norman Wells region currently is being revised as a result of recent surface studies undertaken by the Geological Survey and various commercial firms, together with newly acquired subsurface data. Turonian pelecypods discussed by Jeletzky (1971a) probably are from the Slater River Formation (Yorath *in* Aitken and Cook, in press), instead of from the Little Bear Formation, since other fossils ranging in age from Late Albian to Turonian have now been described from this unit (Yorath, op. cit.). If this is so, the bentonitic shale unit is correlative with the lower part of the Boundary Creek Formation. The Little Bear Formation, consisting of nonmarine and marine clastic rocks, now is dated as Santonian to middle Campanian on the basis of palynomorphs identified by W.W. Brideaux (Yorath, op. cit.). The large Santonian *Inoceramus* ex gr. *cardissoides*-

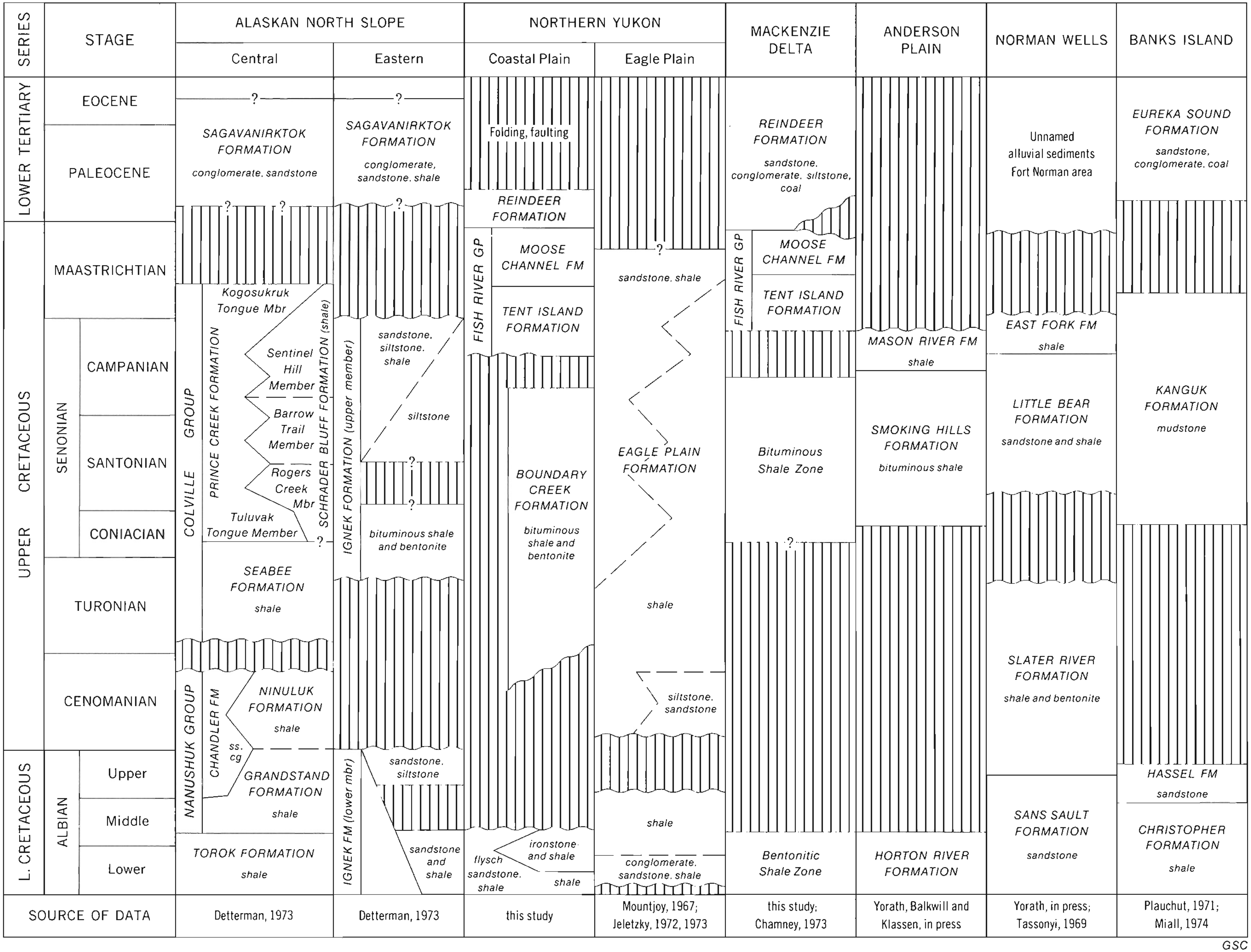

Table 5. Correlation of Upper Cretaceous formations, northern Alaska and northwestern Canada

pinniformis discussed by Jeletzky (1971, p. 58) also is believed now to be from the Little Bear Formation (Yorath, op. cit.). The overlying East Fork Formation has yielded Campanian to early Maastrichtian palynomorphs according to W.W. Brideaux (unpublished internal report K5-WWB-1973). Hence, the East Fork is correlative with the Tent Island Formation, and the Little Bear with the upper Boundary Creek Formation.

Other outcrops in this region have yielded younger microfloral assemblages similar to those of the Aklak Member. These include one of late Maastrichtian to early Paleocene age on Police Island in the Mackenzie River (GSC locs. C-16889 to C-16892, Paleont. Rept. K7-WWB-1972), and a similarly dated assemblage from Grizzly Bear Mountain on the west side of Great Bear Lake (GSC loc. C-4301, reported *in* Balkwill, 1971, p. 22).

Anderson-Horton Plains

The "Pale Shale Zone" (Mason River Formation of Yorath *et al.*, in press) of Anderson and Horton Plains is dated tentatively as late Campanian in age on the basis of sparse microfauna recovered by Chamney (*in* Yorath and Balkwill, 1970). Thus, the "Pale Shale Zone" probably is correlative with the Tent Island Formation.

The "Bituminous Shale Zone" (Smoking Hills Formation of Yorath *et al.*, in press) consists of black shale with beds of jarosite and hematite similar to the Boundary Creek Formation, although the latter perhaps is not so bituminous. The correlation of these units is documented by the similarity of microfossil remains (Chamney, 1972), including radiolarians, foraminifers, fish scales and vertebrate bones found in both units. Also, Russell (1967) unearthed vertebrate fossils from the "Bituminous Shale Zone" ("brown beds") which are similar to those of the early Campanian Niobrara Chalk. These fossils, including pelecypods which were identified by Jeletzky (1971a) and assigned a Santonian to early Campanian age, support a correlation of the "Bituminous Shale Zone" with the upper Boundary Creek Formation.

Arctic Islands

According to Plauchut (1971), the age of the shaly Kanguk Formation is Santonian to Maastrichtian and is preserved over a large part of the Sverdrup Basin, including Banks Island. Micropaleontological work by W.V. Sliter on samples from recently drilled wells on Banks Island indicate a time-range from Cenomanian to Campanian for the Kanguk (*in* Miall, 1974). Palynological studies of the same unit in the Elf *et al.* Storkerson Bay A-15 borehole by W.S. Hopkins suggest an age more restricted to the Senonian (Paleont. Rept. K-10-WSH-1973). Ammonites and pelecypods, including the *Inoceramus lobatus-cardissoides-steenstrupi* species group, indicate a Santonian and possibly Campanian age for the Kanguk according to Jeletzky (1971a, p. 59, 66). The above evidence shows that the Kanguk Formation can be correlated with both the Boundary Creek and Tent Island Formations. It is interesting to note the similarity in age and lithology, including the peculiar cone-in-cone limestone beds (Miall, 1974), between the Kanguk Formation and the equivalent Tent Island Formation of northern Yukon.

The Eureka Sound Formation, a largely arenaceous, nonmarine unit, which overlies the Kanguk in much of the Arctic Islands, is generally early Tertiary in age (Plauchut, 1971) and, therefore, is correlative with the Reindeer Formation. In places where continuous sedimentation above the Kanguk shale has occurred (H. Balkwill, pers. com.), the age of the Eureka Sound extends down into the Maastrichtian Stage (W.S. Hopkins, Paleont. Rept. K-22-WSH-1972). Thus, its oldest members probably are equivalent in age to the Aklak Member of the Reindeer Formation. Future detailed studies of the Eureka Sound Formation may reveal a complex tectonic-sedimentary history (K. Roy, pers. com.) similar to the stratigraphic record of the Fish River Group and overlying Reindeer Formation.

Alaskan North Slope

In central to western parts of the Alaskan North Slope, the Colville Group is the approximate equivalent of the Boundary Creek Formation and Fish River Group. At the base of the Colville Group, the Seabee Formation contains ammonites and pelecypods of Turonian age (Cobban and Gryc, 1961), and is correlative with the lower part of the Boundary Creek Formation (Jeletzky, 1960, p. 22) which it resembles lithologically. The Schrader Bluff Formation which overlies the Seabee contains a fossiliferous medial unit, the Barrow Trail Member, which has yielded *Inoceramus steenstrupi* and *I. patootensis* (Jones and Gryc, 1960). These pelecypods attest to a Santonian to early Campanian age for this part of the Schrader Bluff, and allow correlation of the unit with the upper part of the Kanguk Formation, the "Bituminous Shale Zone" (Smoking Hills Formation), and the upper part of the Boundary Creek Formation (*see* discussion of Anderson-Horton Plains).

Although fossil documentation is lacking, the Sentinel Hill Member of the Schrader Bluff Formation and the overlying Kogosukruk Tongue of the nonmarine Prince Creek Formation probably may be correlated generally with the Tent Island and Moose Channel Formations, respectively. In support of this suggestion, C.J. Smiley commented on the similarities of the florules between the Moose Channel Formation and those of northern Alaska as follows (written com., 1972):

> ...the Moose Channel Formation seems definitely to correlate with the Kogosukruk Tongue of the nonmarine Prince Creek Formation in northern Alaska, and most likely with the lower part of the tongue that interbeds with the marine Sentinel Hill Member of the Schrader Bluff Formation.

T.P. Chamney (written com., 1972) also has confirmed the similarity of foraminifer assemblages between the Tent Island and Schrader Bluff Formations.

In the eastern part of the Alaskan North Slope, southeast of Prudhoe Bay, the Upper Cretaceous is represented by the upper member of the Ignek Formation. This unit is poorly dated, and is given a tentative age-range of from Turonian to Maastrichtian by Keller, Morris, and Detterman (1961), and from Turonian to latest Campanian by Detterman (1973). It is interesting to note that the lower part of the upper Ignek consists of organic shale with bentonite and tuff beds, similar to the approximately equivalent Boundary Creek Formation. The appearance of increasing amounts of coarse clastic material upward in the upper Ignek is a trend parallel to that observed in the Fish River Group of Yukon Coastal Plain, although the latter group is apparently almost a stage younger.

Another poorly dated clastic unit, the Sagavanirktok Formation, unconformably overlies the Ignek on the Arctic coastal plain, and consists of poorly consolidated conglomerate, sandstone and shale of nonmarine origin (Keller *et al.*, 1961). This unit contains plant remains dated as early Tertiary, but contains microfossils more akin to the Cretaceous (op. cit.). The similarity of fossil remains and lithofacies of the Sagavanirktok to the Reindeer Formation suggest a gross correlation of the two units.

PROVENANCE AND PALEOGEOGRAPHY

Several independent sources of information have a bearing on the nature and location of source-areas, the directions of dispersal of detritus, and the main paleogeographic elements at various instants in time. These data include mineralogy of the detritus, ages of recycled pollen and spores, clastic grain-size trends, paleocurrent measurements from sedimentary structures, and facies trends. An integration of these features, plus a knowledge of regional stratigraphic and tectonic features, provide an overall geological framework in which to view the Fish River Group.

COMPOSITION AND ORIGINS OF CLASTIC DETRITUS

The arenites of the Fish River Group and Reindeer Formation contain abundant quartz, chert, and various sedimentary, metamorphic, and volcanic lithoclasts (*see* discussion under heading Sandstone petrography). These components directly reflect the diverse lithologies of the source-areas. Conglomerates of this sequence tend to be far more enriched in chert than the sandstones and, as suggested by D.K. Norris (1971), indicate derivation from "uplifted Neruokpuk and Road River terranes". The abundance of chert in lower Paleozoic strata in the Barn Mountains is depicted clearly in a cross-section by Lenz and Perry (1972). Also, the Carboniferous Lisburne Group contains much chert and cherty carbonate rock (Bamber and Waterhouse, 1971) in the Barn and British Mountains. Green chert fragments, easily mistaken for glauconite, can be traced to Devonian outcrops (Norris, 1970) like those southeast of Bonnet Lake.

Schistose and metaquartzite fragments probably were derived from metamorphic terranes of the Neruokpuk Formation such as that of British Mountains, and from deformed lower Paleozoic strata in Barn Mountains.

The feldspar contents of the sandstone units generally vary with the abundance of igneous rock fragments, a relationship that suggests that the feldspars were derived directly from igneous rocks. In particular, plagioclase feldspar is common typically where volcanic lithoclasts are abundant, and potash feldspar is abundant where granitic phenoclasts occur in associated conglomerates. The latter phenomenon is true especially for the basal Moose Channel Formation at Big Fish River. Hence, plagioclase probably was derived mainly from igneous terranes rich in volcanic rocks, and potash feldspar was derived mainly from exposed granitic stocks. In support of this, it should be noted that older sandstone and carbonate rocks, as well as metamorphosed varieties in the surrounding region, contain very little feldspar, thereby precluding these rocks as major sources of feldspar.

The origin of these igneous rock fragments and feldspars is somewhat of a mystery because of the remoteness, scarcity, and diminutive sizes of igneous terranes exposed today. Speculating on the origin of andesitic phenoclasts in Moose Channel conglomerates, Norris (1970) suggested they were derived from Alaska. In the Brooks Range of northern Alaska, immediately west of the Canadian border, the Neruokpuk Formation contains volcanic rocks (Dutro *et al.*, 1972). Also basalt, gabbro and quartz diorite, dated as Jurassic in age, occur in the Porcupine River area in eastern Alaska (Imlay and Detterman, 1973).

Norris (1972a) indicated the existence of Cambrian volcanic rocks in the British Mountains, but other occurrences of volcanics in northern Yukon are rare; Dyke (1972) noted some in the Proterozoic section in the White Mountains of the northern Richardson Range.

The distribution of volcanic detritus and feldspars by area and stratigraphic level in the Fish River Group is instructive for determining source-areas. These materials are common relatively in the basal part of the group (Cuesta Creek Member) in the western outcrop area, but are rare in the Big Fish River area at similar stratigraphic levels. This distribution suggests detritus was derived from the volcanic rocks of the Brooks Range and deposited in the Deep Creek area, but did not reach the area farther east. A reversal in abundances occurs, however, in the basal and medial Moose Channel Formation, in which volcanics and feldspars are much more common in the eastern outcrop area and in the Ellice O-14 borehole than in the western outcrop area. The proportion of volcanics plus plagioclase in analysed sandstones of the Moose Channel Formation reaches a maximum of 38 per cent in a sample from Big Fish River, but is, on the average, most abundant at Eagle Creek (Table 4) in all three members. Strangely enough, sandstones analysed from the type Aklak Member on Aklak Creek are impoverished in volcanic lithoclasts (approximately 1%) relative to the amounts in similar rocks from Eagle Creek (3%) and the Ellice O-14 borehole (7%). The erratic distribution of volcanic lithoclasts among closely spaced localities indicates very poor blending of detritus by the drainage system, and suggests a closer source of detritus than the Brooks Range. Also, the larger amounts of volcanic detritus in the Moose Channel Formation in the Mackenzie Delta area suggests the relatively close presence of a large volcanic terrane. This terrane is presently not evident, and requires speculation regarding its location. One possibility is that the volcanics now are totally eroded, but at one time may have been associated with granitic stocks such as those of the Barn Mountains. Another possibility is that the volcanics were derived from presently submerged rocks beneath the Beaufort Sea, or from presently mantled outcrops on the lower coastal plain.

GRAIN-SIZE TRENDS

As a guiding principle it can be assumed that the mean size and largest size of clastic fragments decrease downstream from their point of derivation (Leopold *et al.*, 1964), in part due to the action of abrasion and fracturing during transport (Sternberg, 1875). Maximum diameters of the largest phenoclasts were measured in the field at most localities in order to aid in the determination of paleodispersal trends.

The basal unit, the Cuesta Creek Member of the Tent Island Formation, contains the largest phenoclasts on the average as well as the largest in particular. A boulder of chert arenite, three feet (1 m) in largest dimension, was observed above the unconformity on Hornet Creek, and on Trail River blocks of sandstone up to 10 feet (3 m) on a side are present. Clasts this size must be very close to their sources, perhaps in the order of only a few miles.

A map showing maximum phenoclast sizes (Fig. 29) indicates a general northward trend of fining of fragments in the area east of Blow River. This trend is interrupted by major projections of very coarse material on Hornet and Eagle Creeks, suggesting that transport energy was concentrated there probably as a stream channel directed toward the northeast. Maximum sizes decrease rapidly to the northwest and indicate slack-water conditions near a shoreline close to the mouth of present-day Rapid Creek.

A similar map with more control points can be drawn for the basal sandstone member of the Moose Channel Formation in the eastern outcrop area (Fig. 30). In this case there is a fairly regular north- and northeastward decrease in the maximum diameters of phenoclasts, ranging from 300 millimetres at Little Fish (Cache) Creek to 40 millimetres in the Ellice O-14 borehole. This trend closely parallels the dispersal directions indicated by measurements of current-formed structures. The maximum value (110 mm) observed from the Deep Creek outcrop area suggests that this size is not as close to the source-area as the entire eastern outcrop region, although other factors, such as relative relief in the source-areas, also could account for these differences.

Too few data points are available to plot maps for the Tent Island Formation and Ministicoog and Aklak Members. However, the maximum sizes observed in the Aklak Member on Aklak Creek and Eagle Creek (300 mm and 400 mm, respectively) greatly exceed the respective values of the Moose Channel Formation. This, together with the markedly nonmarine character of the Aklak compared to the Moose Channel, suggests that the source-area of the Aklak was closer to the present outcrops than that of the Moose Channel Formation.

AGES OF RE-CYCLED MICROFOSSILS

Palynological samples from various localities and stratigraphic levels in the Fish River Group and Reindeer Formation commonly have yielded abundant re-cycled pollen and spores (W.W. Brideaux, internal reports). This material is useful in determining the provenance of clastic detritus because it can be accurately dated. All members of the sequence contain about the same assemblage of re-cycled palynomorphs, the dominant ones being Early Cretaceous forms. Less common are early Paleozoic, Carboniferous, Permian and Triassic spores. Sedimentary rocks of these ages outcrop today in northern Richardson Mountains, Barn Mountains and Porcupine Plateau. Triassic rocks are restricted to northern Barn Mountains and eastern British Mountains (Mountjoy, 1967b), and possibly eastern and southern Richardson Mountains (Jeletzky, 1967). Hence, detritus forming the Fish River Group and Reindeer Formation must have been derived from some or all of the above localities, as well as from the present large area to the southwest where Lower Cretaceous strata are exposed. These areas also include large tracts of Jurassic outcrops, and it is difficult to understand why Jurassic palynomorphs have not been recognized in the re-cycled assemblages. Possibly many of the Jurassic palynomorphs are long-ranging varieties which cannot be differentiated from the Early Cretaceous forms.

PALEOCURRENT MEASUREMENTS

Sedimentary structures used to determine paleocurrents include cross-stratification, scour-axes, ripple-marks, and current lineations. The latter two provide orientations only, and independent evidence is required to determine the directions of paleocurrents. The 184 readings are grouped into 17 stations, each of which generally includes readings from numerous different beds scattered throughout an entire member.

Directional data recorded in the field were corrected for simple tectonic tilting by means of a stereonet, using the method explained by Potter and Pettijohn (1963). Corrected data were grouped into 30-degree sectors. The percentages of readings falling into each sector were plotted as circular histograms (Figs. 29, 30). Resultant vectors were calculated and plotted on the maps only if the vector strengths indicated statistical significance at a confidence level greater than 95 per cent (Curray, 1956, Fig. 4).

Paleocurrent measurements in the Cuesta Creek

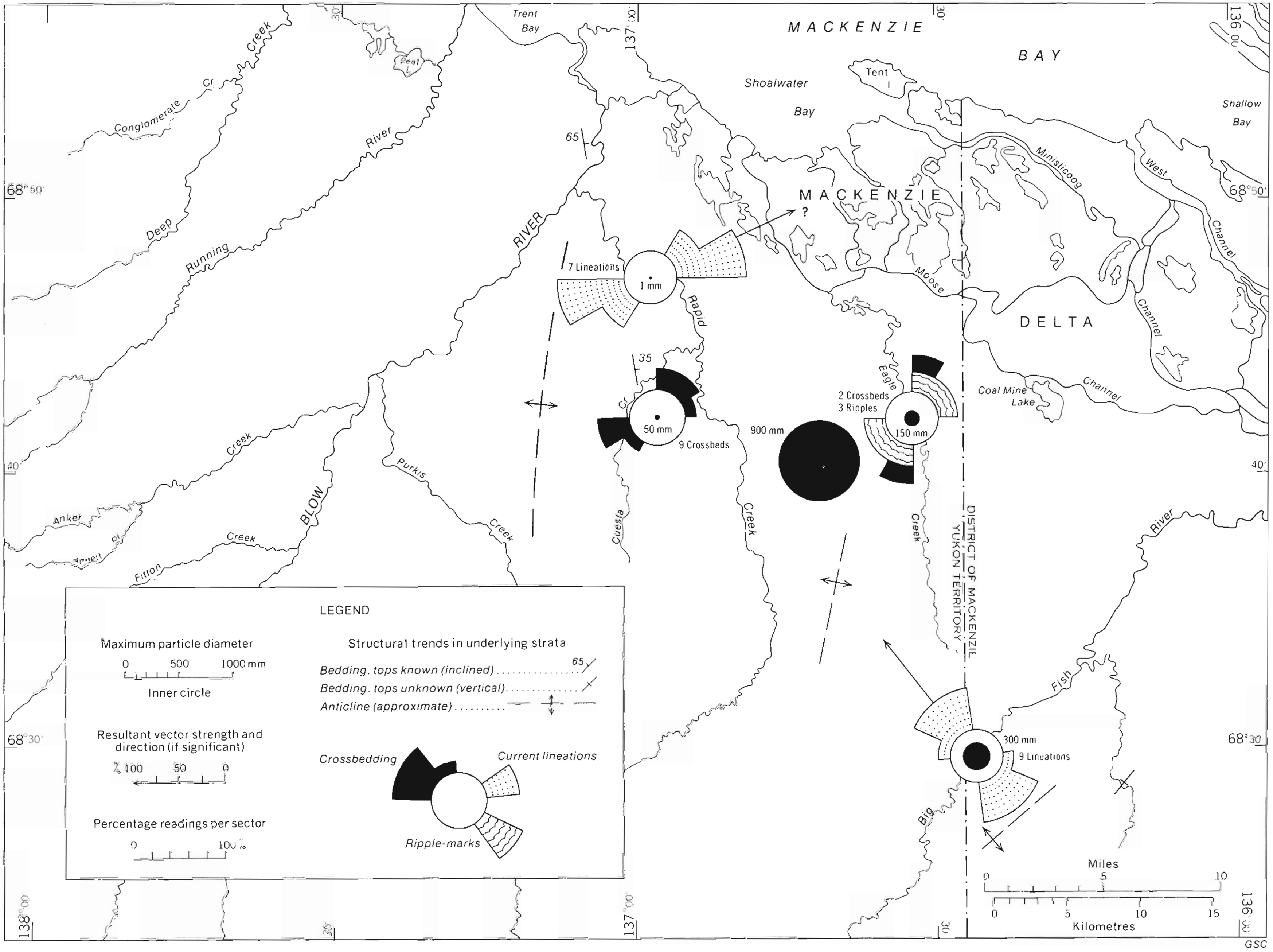

Figure 29. Paleocurrents and phenoclast maxima in Cuesta Creek Member

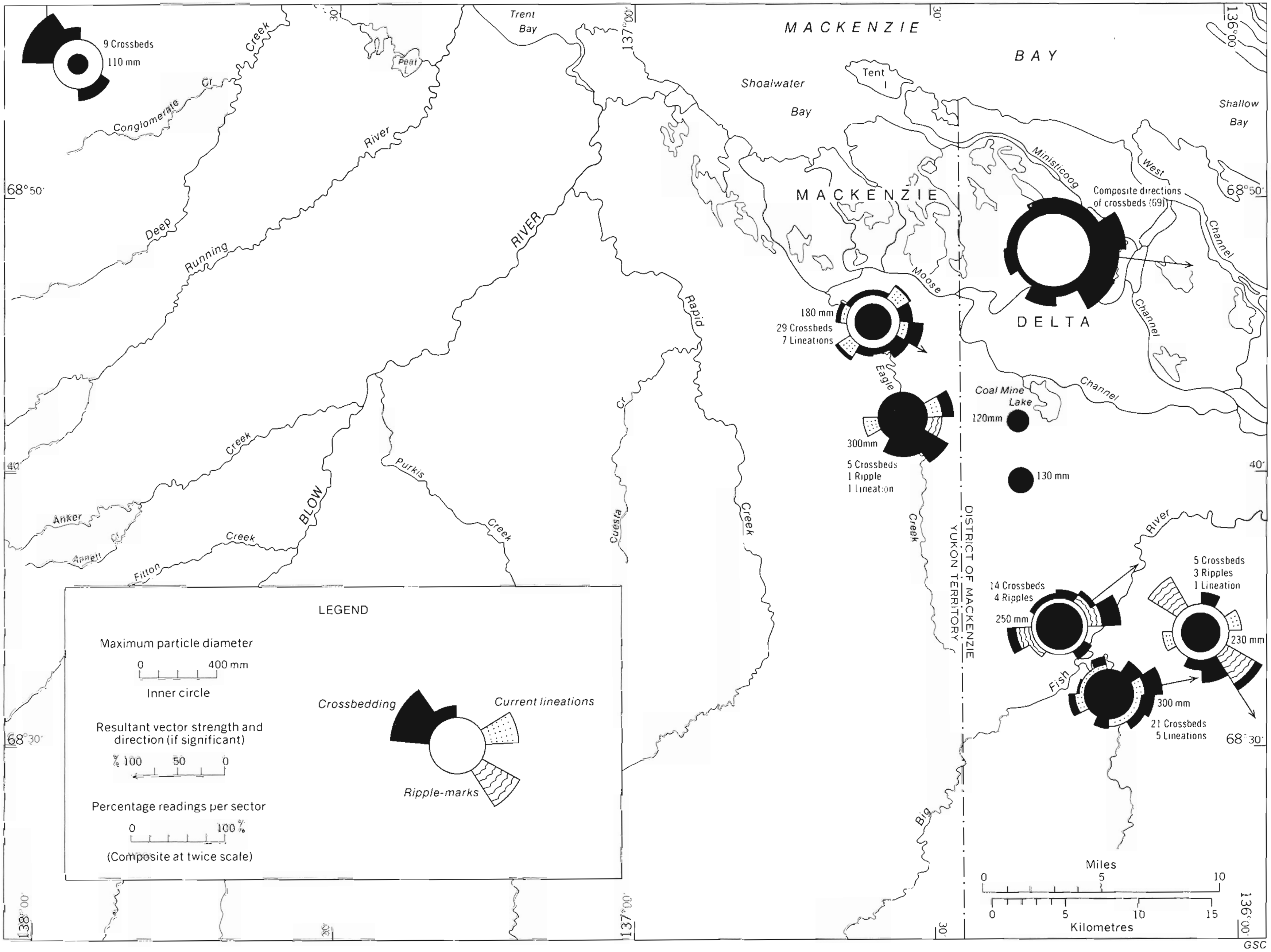

Figure 30. Paleocurrents and phenoclast maxima in the basal sandstone member, Moose Channel Formation

Member are concentrated in the eastern outcrop area (Fig. 29), where four different stations show no single, consistent trend. At Big Fish River, climbing ripples indicate that the general direction of current flow which produced the measured current lineations was north-northwest. At the other three stations the paleocurrent distributions are bimodal, with modes diametrically opposed. Such distributions are typical of strandline and tidal flat deposits (Klein, 1967) where wave- and tide-generated currents run both toward and away from the shore. From other data, such as grain-size trends, it is reasonable to assume that the land lay southwest of these locations.

The dispersal pattern thus outlined by these few stations indicates an interesting relationship to the present structural and outcrop trends, by which the paleocurrents at each station are roughly orthogonal to the outcrop trends. This relationship supports an hypothesis suggested to the writer by J.S. Bell of Shell Canada Limited, who believes that structurally elevated areas in the underlying Lower Cretaceous and older rocks may have been topographically high during Upper Cretaceous sedimentation, and that folds in the latter sequence developed along much the same lines as did the underlying folds. Thus, dispersal directions in the basal Fish River Group would naturally be perpendicular to the flanks of structural highs in the underlying rocks.

In the basal Moose Channel Formation, paleocurrent trends are less well defined, partly because of the higher variance in directional values at each station. In the eastern outcrop area, the dominant paleocurrent trends appear to be in an easterly direction (Fig. 30). If the crossbedding dip-directions of all four stations are grouped (69 readings), the resultant vector gives a direction of S83°E, with a 99.99 per cent chance that this value is not due to random causes.

A collection of readings from the Moose Channel Formation in the Deep Creek area indicates a northwestward dipping paleoslope. The inlier of suspected Upper Cretaceous strata in Blow River valley provided paleocurrent orientations aligned roughly north-south.

Paleocurrent directions in the Ministicoog Member are extremly variable in both the western and eastern outcrop areas (Fig. 31), typical of sediments dispersed in shallow-marine waters (Klein, 1967; Dott and Roshardt, 1972). The tidalite facies on Eagle Creek shows consistent north-northeast to south-southwest paleocurrent orientations, as well as northeast-directed current ripple-marks. These orientations are consistent with facies trends in the member, in which tidal flat sediments grade laterally toward the north and east into a shallow-neritic-zone mud facies, as expressed on lower Eagle Creek, Aklak Creek, and Big Fish River.

The Aklak Member at Aklak Creek shows an essentially unimodal paleocurrent pattern from 15 crossbedding dips whose resultant vector is N80°E. A few miles west, on Eagle Creek, the extremely sandy Aklak contains crossbeds directed easterly, ripple-marks oriented northeast-southwest, and scour-axes directed toward the southeast.

PALEOGEOGRAPHIC SUMMARY

Dispersal trends and the petrography of clastic particles indicate that, in general, the source of sediment and heads of dispersal systems lay to the west and south of the present coastal plain and that receiving basins for sedimentation lay beneath Yukon Coastal Plain, Beaufort Sea shelf, and Mackenzie Delta. A cursory examination of any columnar stratigraphic section of the Fish River Group, however, reveals that there occurred both large- and small-scale fluctuations in sedimentary facies and shoreline position. Large-scale vertical stratigraphic changes, from base to top include: (1) alluviation (Cuesta Creek Member), (2) marine inundation (Tent Island Formation), (3) deltaic and alluvial progradation (basal member, Moose Channel Formation), (4) marine inundation (Ministicoog Member), and (5) deltaic and alluvial progradation (Aklak Member, Reindeer Formation). At a single location these vacillations are manifest to varying degrees, and small-scale reversals are typical within the large-scale trends. This type of cyclicity is commonly conceived in terms of transgressive and regressive phases of sedimentation with respect to shifts in shoreline position. That is, during the marine inundation represented by the Tent Island Formation, for example, the shoreline transgressed landward and was probably stationed well into the upland areas. Subsequently, during progradation and construction of coarse clastic wedges, the shoreline necessarily regressed seaward, and was located somewhere near the present coastline or farther north. During the regressive phases, a coastal plain sedimentary wedge became established which could be considered ancestral to the present-day Yukon Coastal Plain.

Paleodispersal trends show clearly that the Fish River Group was not deposited from a proto-Mackenzie River. Rather, the locally derived detritus and eastwardly directed paleocurrents indicate the existence of a highland which formed a drainage divide between the coastal plain area and Eagle Plain to the south, similar to the present physiography. The presence of a south-bounding highland together with eastward dispersal suggests the existence of a major eastward-flowing river which headed in Brooks Range, and followed structurally controlled topographic depressions. The north-south structural trend in the lower Blow River area may have formed a northward-projecting topographic salient, which deflected the hypothetical river north onto the present Beaufort Sea shelf, from whence it curved back toward Mackenzie Delta (Fig. 32). Variable paleocurrent directions in the Cuesta Creek Member support the concept of consequent drainage of tributary streams, at least at the commencement of deposition of this sequence.

Deltaic sedimentation and the loci of depocentres appear to have been concentrated in the lower coastal plain and subsurface of the present Mackenzie Delta. Marine shale tongues and deltaic facies are far more common in the I.O.E. Ellice 0-14 section than in any surface section to the southwest. In the eastern outcrop area, during regressive episodes, shoreline and coastal plain environments were most common.

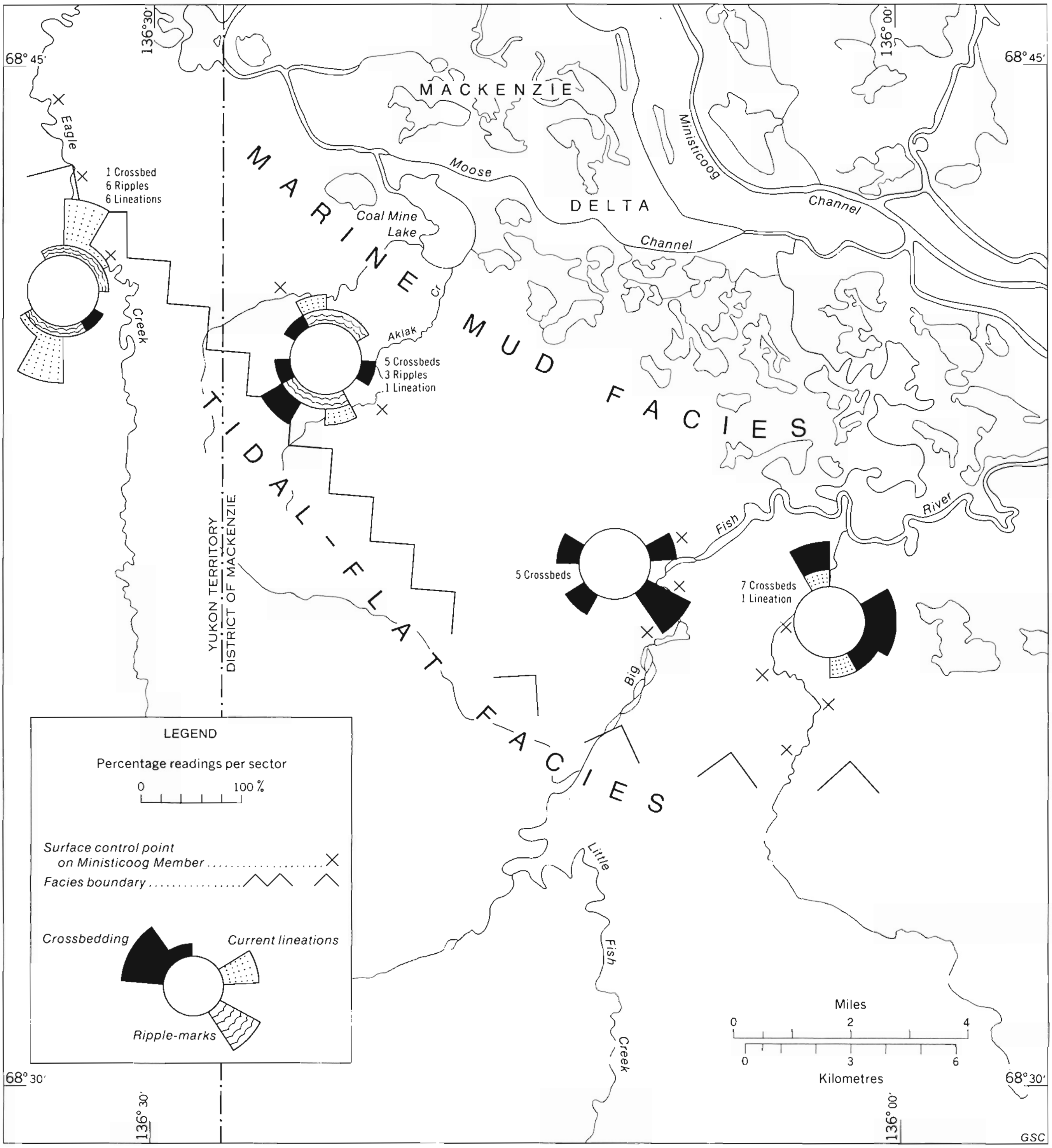

Figure 31. Paleocurrents and facies trends in the Ministicoog Member, Moose Channel Formation

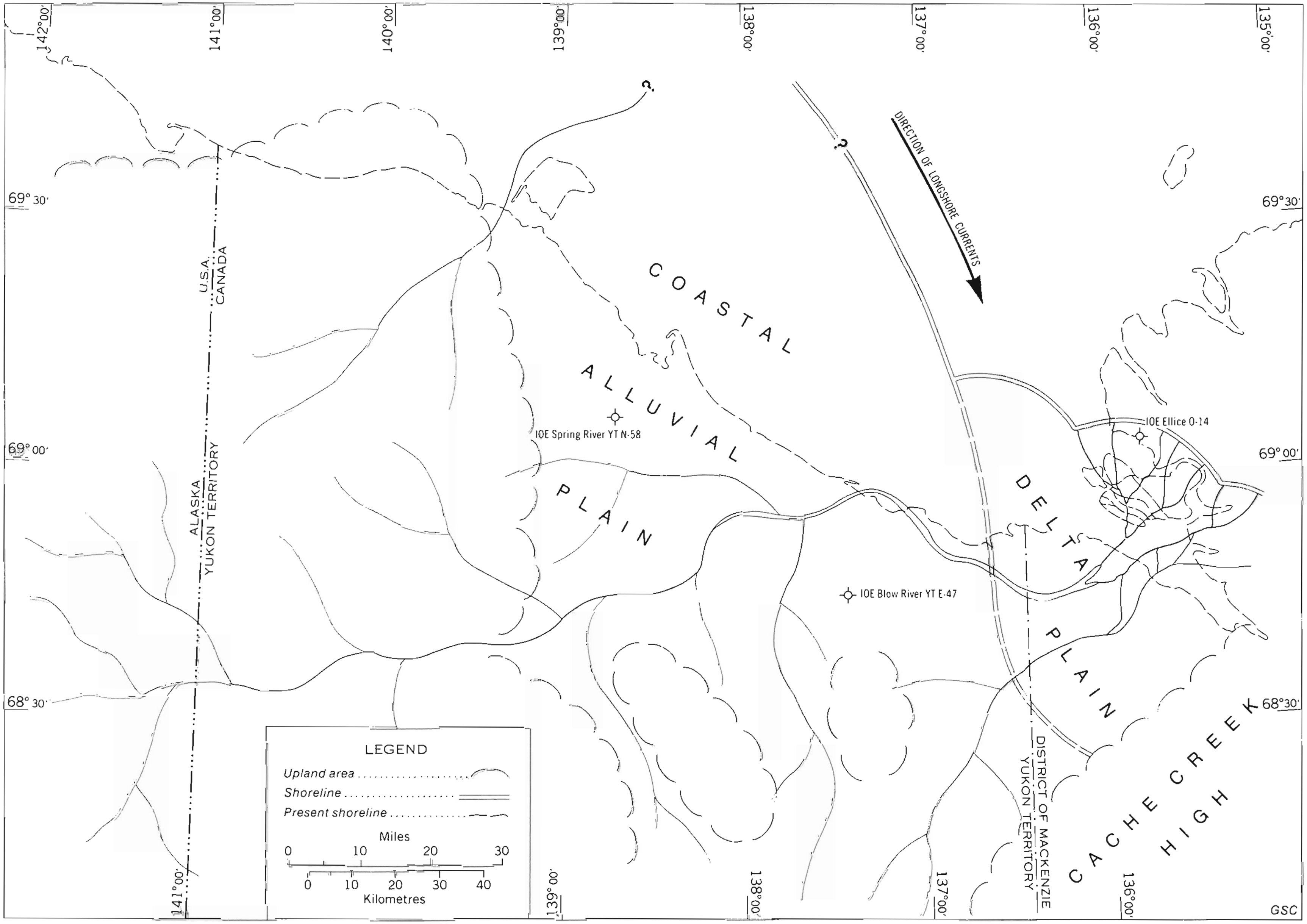

Figure 32. Paleogeographic reconstruction of Yukon north slope during deposition of basal Moose Channel Formation

The Fish River Group, comprising a mixture of nonmarine, transitional and marine sedimentary rocks composed of immature, re-cycled detritus, is a molasse-like suite. This interpretation is appreciated best when the evaluation of the group is reviewed along with the entire Mesozoic history of sedimentation and tectonics of the area (Young, 1974). But even from a restricted viewpoint, certain features of the Fish River Group are similar to features in the Subalpine Molasse of central Europe (pers. com., F.B. Van Houten). For example, the immature polymictic sandstone, lenticular conglomerate, and freshwater carbonate units and coal seams are all features common to each series. Also, the Tonmergel forming the Lower Marine Molasse at the base of the Subalpine Molasse is strikingly similar in lithology and stratigraphic setting to the bluish grey, thin-bedded mudstones with calcareous interbeds comprising the Tent Island Formation.

STRUCTURAL GEOLOGY

The dominant structural grain in Upper Cretaceous strata of Yukon Coastal Plain is north-south, and is expressed in the axial trends of broad upright folds and in the strikes of high-angle normal faults. Smaller areas, mainly in the vicinities of Big Fish and Babbage Rivers, display a northwest-southeast structural alignment. A set of normal faults, but no fold-axes, strike east-west to northeast-southwest, and strata within two miles (3.2 km) of the Cache Creek Uplift in the southeast corner of the map-area (Fig. 1) strike northeast-southwest, parallel to the uplift.

The Boundary Creek Formation commonly is deformed complexly, but displays fold axes sub-parallel to the structural grain of the underlying Albian strata and overlying Fish River Group. Bedding dips in the Boundary Creek generally exceed slightly those of the Fish River Group.

Strata of the Fish River Group in the map-area and in the Deep Creek Syncline are gently to moderately tilted and transected by high-angle normal faults (Norris, 1972a). Mountjoy (1967a) stated that the Moose Channel Formation has a northwest-southeast strike in contrast to the north-south structural grain of the Richardson Mountains which border the map-area on the south. This is largely true near Big Fish River, but farther west a north-south strike prevails, parallel with that of the underlying strata. On Big Fish River the strata dip northeast with dips ranging from 3 to 7 degrees. At most other creek exposures in that area, however, dips are somwhat higher in the range of 10 to 25 degrees. Along Eagle Creek, Moose Channel and Reindeer strata dip eastward at angles ranging from 25 to 50 degrees.

On the southwest shore of Coal Mine Lake, a vertical bed of Aklak conglomerate forms a prominent outcrop, and coal beds mined adjacent to it also are oriented vertically. This unusual structural configuration is due possibly to either drag-folding adjacent to a major fault, or rotation of a small wedge caught between two fault splays. In either case, the lateral extent of the vertical beds would be limited.

Folding and tilting of strata of the Fish River Group appear to have occurred along the same rotational axes as those in the underlying Albian shales and Boundary Creek Formation. For example, the north-trending cuesta formed by the Cuesta Creek Member has the same strike as the underlying Albian and younger shales, but the dips of the Cuesta Creek beds are only 10 to 15 degrees east whereas the dips of the older rocks range between 35 and 60 degrees east. Similarly, in the Deep Creek Syncline the Fish River Group strata comprise the youngest rocks in the axial part of the fold and are either horizontal or inclined generally at less than 25 degrees. Dark grey Albian shales, however, which underlie the Fish River Group, dip at 40 to 60 degrees in the western limb of the syncline. The gradual decrease in dip toward the fold-axis indicates a cylindrical type of folding during the final tectonic phase. The same type of coaxial folding occurs in the subsurface of the continental shelf to the north according to continuous seismic profiles (Yorath, 1973, Fig. 5).

Folding about north-south axes appears to have occurred prior to most of the faulting, because the folds are truncated in various ways, or appear as simple monoclines between two sub-parallel faults. In the eastern part of the coastal plain (Fig. 1), the northeast-trending faults generally are truncated by the north-trending faults, suggesting that the latter are the younger features. The north side is generally down-dropped with respect to the south block across most of the northeast-trending faults, suggesting a genetic relationship to the similarly trending, fault-bounded Cache Creek Uplift (Norris, 1973). Accordingly, this feature must have been reactivated after the Fish River Group was deposited, probably in early Tertiary time.

Faults that offset large blocks of Fish River strata also extend into the Albian and older rocks of the adjacent northern Richardson Mountains and comprise the major faults in that region. The older rocks, in addition, contain more closely spaced faults and tighter folds, oriented mainly along north-south or northeast-southwest axes, that were probably formed prior to late Upper Cretaceous sedimentation.

This deformation, plus the fact that Fish River Group sediments overstep the Boundary Creek Formation and onlap older shales on Hornet Creek, in the sense suggested by Mountjoy (1967a), indicate that tectonism occurred in early to mid-Late Cretaceous time. Also, a post-depositional tectonic episode must have affected the Upper Cretaceous and early Paleocene sediments and probably caused much mountainous relief. This is suggested by the occurrence of thick wedges of Eocene and younger coarse clastic sediments in the subsurface of Mackenzie Delta that probably were derived from such Laramide uplifts.

ECONOMIC GEOLOGY

The Fish River Group and Reindeer Formation are important economically because of their coal deposits and probable petroleum and natural gas reserves.

COAL

Coal seams are thin and rare in the Moose Channel Formation but are relatively thick and numerous in the Reindeer Formation. Coal was mined at Moose River Mine on the western bank of Mackenzie Delta from vertical beds in the Aklak Member. This mine operated successfully for many years, supplying coal for domestic use in the Aklavik area until 1956 when the mine was abandoned. Coal samples from this mine, submitted to the Mines Branch by B.A. Latour for analysis, were classified as subbituminous "A" to high volatile "C" bituminous in rank, and determined to have a calorific value of 11,080 B.T.U. per pound (Mines Branch, Fuel Research Lab Report 2926-55).

On Aklak Creek, which flows into Coal Mine Lake where the mine was located, two coal beds outcrop, the lower being about 23 feet (7 m) thick, and the higher, some 250 feet (76 m) stratigraphically above, being 12 feet (3.7 m) thick. Both units contain about 30 per cent coaly mudstone interbeds. Faults cause difficulties in determining the areal extent of these seams, including those mined. It is estimated, however, that at least 6,800 acres (2,750 hectares) must be underlain by substantial coal seams from the surface to a depth of less than 1,500 feet (460 m). Coal seams up to 3 feet (0.9 m) thick also were noted on Eagle Creek, and were reported by D.K. Norris (1972a) from the Deep Creek area (Lat. 68°53'N, Long. 138°02'W).

Coal samples from various outcrop localities and from the I.O.E. Ellice O-14 and Gulf *et al.* Reindeer D-27 boreholes were analysed for vitrinite reflectance by P. Gunther of the Geological Survey (Table 6). As determined from empirical curves relating proportions of volatile matter to reflectance values, the comparable A.S.T.M. coal ranks range from high-volatile bituminous-A to -C. Note that coal from Eagle Creek is of slightly higher rank than that of the Big Fish River area. This trend reflects the gradual increase in paleotemperatures and tectonic deformation from east to west toward Blow River. Coal samples from the Reindeer D-27 borehole are lower in rank than those of the Ellice O-14 well or the outcrop samples. The Trail River sample is comparable in rank to the coals of Big Fish River and the Ellice borehole.

PETROLEUM

Prospective formations

Sandstone units in the Fish River Group and overlying Reindeer Formation are good prospective reservoirs for petroleum and natural gas in the subsurface of northwestern Mackenzie Delta and adjacent Beaufort Sea shelf (Lerand, 1973). Intertonguing deltaic and marine shale facies, such as those exhibited by these rocks, constitute zones of prolific petroleum production in many areas, including the Gulf Coast of southern U.S.A. (Lowman, 1949; Rainwater, 1963). Substantial gas reserves already are indicated in transition-zone facies of the Reindeer Formation in the Taglu field under northern Mackenzie Delta.

Marine to nonmarine transition zones in the Moose Channel and Reindeer Formations, and isolated thick developments of the Cuesta Creek Member, comprise the main prospective parts of the Upper Cretaceous-Lower Tertiary sequence.

In the Moose Channel Formation, the delta-plain facies is transitional with marine mudstones in the I.O.E. Ellice O-14 borehole (Figs. 32, 33). This borehole probably lies within a northwest-southeast trending zone which passes through Ellice and Langley Islands marking the area most favourable for finding trapped hydrocarbons in this formation. The delta-plain facies (Aklak Member) of the lower Reindeer Formation apparently extended farther to the northeast than that of the Moose Channel Formation (Fig. 33). This is indicated by its presence in the Ellice O-14 borehole, onshore paleocurrent trends, and its transition-zone character in the Taglu G-33 borehole. This prospective zone, which includes the Taglu field, probably trends northwest-southeast under southwestern Richards Island and the northern part of the Mackenzie Delta Plain.

The largest reservoirs appear to be formed in rollover and domical anticlines associated with growth faults (Lerand, 1973, p. 332). These structures can be located by seismic and gravity surveying (G.K. Sirrine, reported in Oilweek, Nov. 19, 1973), and result in stacked sandstone reservoirs having large net pay thicknesses.

The Cuesta Creek Member of the Tent Island Formation is an important potential reservoir for hydrocarbons, particularly in the vicinity of anticlines beneath the coastal plain and Beaufort Sea shelf (Fig. 33). This sandstone and conglomerate unit has the advantages of being lenticular in nature (Silver, 1973), and being sandwiched between two thick marine shale formations. Factors which detract from its prospectiveness include the presence of fresh water within the unit, breaching of most mapped anticlines on the coastal plain to stratigraphic levels below the Cuesta Creek, and tectonic disturbance in the areas of Rapid Creek and Blow River.

The Cuesta Creek Member was tested in the I.O.E. Blow River E-47 borehole in the depth-interval 3,260-3,403 feet (995-1040 m). Excellent permeability of the tested conglomeratic sandstone is indicated by the 3,050 feet (930 m) of fresh water recovered. Because the sample-cuttings appear nonporous, the good permeability may be due, in part, to open fractures in the rock. Fractures occurring in a core cut from just above the tested interval appear as slickensided surfaces and open tension gashes. Quartz veins and fault-brecciation are present also.

Some factors affecting petroleum potential

Tectonic deformation and its timing relative to deposition and sediment burial, the quality of porosity, and geothermal history all have a bearing on petroleum potential. Following are some findings on these factors which resulted from this research.

LOCALITY OR BOREHOLE	FM.	SAMPLE NO. OR DEPTH IN WELL (FT)	COAL REFLECTANCE		% VM OF VITRINITE (from Kötter's curve)	COMPARABLE ASTM RANK
			Average %Ro	Std. Dev.		
Big Fish River	MC	29 YA	0.70	.038	39	* HVB-A
	MC	34 YA-4	0.63	.041	41	HVB-B
	MC	34 YA-8	0.66	.060	41	HVB-B
	MC	141b YA-1	0.61	.018	42	HVB-B
Aklak Creek	R	13 YAb-1	0.63	.041	41	HVB-B
	R	14 YAb-2	0.63	.049	41	HVB-B
Eagle Creek	R	33a YAb-2	0.71	.039	38	HVB-A
	MC	140 YA-2	0.76	.030	37	HVB-A
Caribou Hills	R	198 YA-7	0.25	.071	>56	Lignite
Trail River	MC	180 YA-4	0.62	.015	42	HVB-B
IOE Ellice O-14	R	4270-4280	0.62	.056	41	HVB-B
	R	5000-5010	0.59	.043	42	HVB-B
	R	5500-5510	0.62	.046	41	HVB-B
	R	5580-5590	0.65	.039	40	HVB-B
	MC	8590-8600	0.68	.080	39	HVB-A
	MC	8920-8930	0.74	.046	37	HVB-A
Gulf-Shell-IOE Reindeer D-27	R	3697-3705	0.55	.018	44	HVB-C
	R	4763	0.48	.075	46	HVB-C
	MC	5310 } separate	0.58	.028	42	HVB-C
	MC	5310 } samples	0.52	.031	45	HVB-C
	MC	6100	0.55	.038	44	HVB-C

*High volatile bituminous

GSC

Table 6. Results of coal reflectance measurements, Moose Channel and Reindeer Formations

As discussed in the previous chapter, the Fish River Group and Aklak Member of the Reindeer Formation west of Mackenzie Delta were folded and faulted during a late Laramide tectonic episode. The north-south aligned folds and faults become more closely spaced in the vicinity of lower Rapid Creek (Fig. 1), commensurate with increased brittleness of shales, quartz veining, and other signs of intensified deformation westward. This tectonism probably resulted in flushing of hydrocarbons by groundwater or hydrothermal waters, reduction of porosity, greater heat flow, and a great reduction in petroleum potential in the Blow River area. West of Blow River, the intensity of deformation lessens, and the petroleum potential, in turn, probably increases.

Porosity of surface sandstones is low due to their high degree of compaction and the presence of calcite cement. Similar textures were noted visually in cores of correlative rocks in the I.O.E. Ellice O-14 borehole. Analyses of core from the Ellice O-14 borehole, however, indicate effective porosities of from 10 to 30 per cent at depths down to about one mile (1.6 km). This is reflected in the fact that 4,850 feet (1480 m) of salt water were recovered during a drill-stem test of the interval 4,866-4,916 feet (1485-1500 m). Porosity gradually decreases downhole to ineffective values according to porosity analyses of cores. A sandstone core from a depth of 7,900 feet (2410 m) showed porosities in the range of only 1 to 10 per cent.

Associated with deep burial is the increase in temperature due to the outward flow of geothermal heat through the earth's crust. Because increased temperature has an important bearing on petroleum genesis and preservation (Philippi, 1965), a brief review of thermal indicators in the Reindeer Formation, Fish River Group and the underlying Albian flyschoid sediments is in order.

Indicators of thermal history include the colour of sedimentary organic matter, coal ranks, and the presence of certain authigenic minerals. These features provide an estimate of maximum temperatures because of their irreversible nature.

The pale yellow and brown colours of spores, pollen and other plant debris recovered from outcrop samples of Fish River Group rocks in the eastern outcrop area indicate low degrees of thermal alteration (Staplin, 1969). Analcime was reported by Holmes and Oliver (1973) in a recrystallized tuff from the Moose Channel Formation on Aklak Creek. In the presence of quartz, analcime becomes unstable at temperatures greater than 200°C and at pressures less than 2,000 bars (Liou, 1971), and converts into albite and water. Hence, its presence indicates that temperatures in the host-rock have never exceeded 200°C.

In the I.O.E. Ellice O-14 borehole, thermal metamorphism of organic materials apparently increases with depth, as Brideaux noted that "(plant) material becomes progressively more carbonized downhole until a dark brown color is reached in cores 10 to 12" (8,873-9,523 feet). The dark brown colour would fall into Staplin's (1969) thermal index 2.5 to 3, and would correspond to temperatures at which both light and heavy hydrocarbons would be generated.

The ranks of coals gradually increase downsection in the I.O.E. Ellice O-14 borehole (Table 6), paralleling the gradual occlusion of porosity and permeability of sandstones, and the increase in brown colouration of palynomorphs. According to some unpublished data relating coal reflectance to temperature, the paleotemperatures in the Ellice O-14 borehole between the depths 4,270 and 8,930 feet (1300-2720 m) were approximately 85° and 103°C (Gunther, Internal Rept. CP73-R3). Hence, paleotemperatures in the Reindeer D-27 well were probably somewhat less than 85°C.

According to Philippi (1965), temperatures of about 150°C were required to generate oil in the young sediments of the Los Angeles Basin but, in the Paris Basin of France, a temperature of only 60°C at a depth of approximately 5,000 feet (1520 m) was sufficient to generate oil from kerogen (Tissot *et al.*, 1971). Possibly a time-factor plays a role in the generation of oil, because the Paris Basin sediments enriched in petroleum are Jurassic in age. Nevertheless, because the Upper Cretaceous rocks considered here lie within the depth-range and temperature-range deemed to be productive of immature gas and oil, they are highly prospective in the subsurface of Mackenzie Delta and offshore coastal areas.

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APPENDIX

DESCRIPTIONS OF STRATIGRAPHIC SECTIONS

Section 1: Type section of Boundary Creek Formation, Boundary Creek, Yukon Territory, on northern bank immediately upstream from confluence with Big Fish River at Lat. 68°30'30"N, Long. 136°23'50"W. Measured partly by D. H. McNeil and partly by T. P. Chamney, June 1971. Aerial photograph A14361-26, top of section at photo co-ordinates X=+0.90 cm, Y=+1.25 cm; base of section at photo co-ordinates X=-3.40 cm, Y=+2.00 cm.

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	Overlying beds: interbedded mudstone and sandstone of Cuesta Creek Member, Tent Island Formation. Contact is covered here, but is believed to be disconformable.		
	UPPER CRETACEOUS		
	Boundary Creek Formation (794±40 feet)		
22	Covered interval	20	794
21	Shale, poorly exposed, interbedded pale grey and pale yellow varieties, the latter probably bentonitic; wavy bedding characteristic; selenite crystals common in scree	80	774
20	Shale, dark grey to black, flaky to papery, in part soft and plastic; 2- to 4-inch bentonite beds common, pale yellow-brown; large septarian nodules up to 5 feet in diameter; selenite encrustations on many bedding planes	46	694
19	Shale, dark grey, papery, with very thin bedded white bentonite; pale yellow coatings common	27	648
18	Silty mudstone, orange-brown to burgundy red marker bed, variegated purplish weathered surfaces	3	621
17	Shale, medium to dark grey, fissile, recessive, orange and yellow weathering; common yellow bentonite layers	30	618
16	Shale, as above, with few clay ironstone concretions; in part papery, darker grey; possible fish scale and bone impressions	30	588
15	Shale, grey, soft, fissile in part, white to yellow bentonite bands becoming more common towards top; minor ironstone concretions	85	558
14	Bentonite marker bed, yellowish white, very soft, homogeneous	1	473
13	Shale, mahogany-brown weathering, relatively resistant, grey; silty, calcareous mudstone beds at top and base, minor hard, flaggy, pale yellow claystone beds	25	472
12	Mudstone, calcareous, dark brown, laminated, irregular bottom surface, even upper surface	1	447
11	Shale, black, grey-black weathering, flaky, petroliferous odour, bentonite seams very common, selenite crystals common; calcareous concretions 1 to 6 inches in diameter	74	446
10	Shale, brown-black, flaky, weathers grey to rusty brown, soft, clayey, recessive, poorly exposed	28	372
9	Limestone, bioclastic and quartz sandy, medium to dark grey, fine grained, light and dark laminae, cross-laminated, thin bedded, interbedded with shale (50%), grey-black	18	344

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
8	Shale, soft, poorly exposed, rare thin beds of calcareous mudstone	40	326
7	Covered interval	55	286
6	Shale, brown-black, clayey, very soft, selenite crystals common, H_2S-odour when struck; two limestone beds, echinodermal calcarenite, rusty weathering, dark grey, fine grained, beds 0.5 foot thick	13	231
5	Shale, as above, with thin bentonite seams very common (1 to 5 feet apart); very thin beds of calcareous mudstone	26	218
4	Interbedded rusty-weathering and black shales	6	192
3	Interbedded rusty and grey shales, capped by hard calcareous mudstone bed, 0.5 to 1.0 foot thick, possibly fine bone impressions; rusty, highly weathered basal bed, 1.5 feet thick	13	186
2	Shale, grey-black, grey weathering, clayey, soft, fine chippy; light grey and yellow bentonitic bands, 5% calcareous mudstone beds, rusty and hackly weathering; selenite crystals common	45	173
1	Alternating types of shale, including soft, grey-black, pyritic, flaky shale with bentonite bands, and rusty-weathering, brown-black shale, moderately hard, chippy; all brick-red weathering, hematitic locally; sharp contact at base	128	128
	Underlying beds: bedded ironstone and shale unit (Lower Cretaceous).		

<u>Section 2</u>: Type section of Cuesta Creek Member, Tent Island Formation, located on northwest bank of Big Fish River just downstream from confluence with Boundary Creek at Lat. 68°30'30"N, Long. 136°23'50"W. Measured by D. H. McNeil, June 1971. Aerial photograph A14361-26; top of section at photo co-ordinates X=+1.15 cm, Y=+1.80 cm; base of section at photo co-ordinates X=+0.90 cm, Y=+1.26 cm.

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	Overlying beds: silty mudstone of Tent Island Formation.		
	UPPER CRETACEOUS (?CAMPANIAN)		
	<u>Tent Island Formation</u>		
	Cuesta Creek Member (326 feet)		
10	Conglomerate (60%) and interbedded sandstone (40%). Conglomerate is rusty grey weathering, pebbly, medium to thick bedded, contains well-rounded phenoclasts of chert and mudstone and medium-grained sand matrix; sandstone is medium grey, weathering grey to rust, medium grained, quartz-chert arenite, very hard, resistant to erosion, medium to thick bedded. Sharp contact with Unit 9	68	326

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
9	Mudstone, shaly, dark brown, grey weathering, silty, chunky fracturing, weathers into brittle chips and flakes. Sharp contact with Unit 8	59	258
8	Sandstone, brown weathering, light grey-brown, medium grained, slightly porous, quartz-chert lithic arenite, medium bedded, resistant to erosion, fractures into angular slabs. Gradational contact with Unit 7	7	199
7	Conglomerate (70%) and interlensed sandstone (30%). Conglomerate, rusty grey, mainly pebbly but phenoclasts up to one foot in diameter, lithic sand matrix, thick bedded to massive, very resistant; sandstone, medium grey, orange weathering in part, medium grained, poorly sorted, subangular quartz and black chert and lithic grains, slightly porous, medium to thick bedded, beds visibly lenticular, very hard and resistant to erosion. Contact with Unit 6 sharp and even	31	192
6	Shale, silty, dark brown, brown-grey weathering, hard, chippy-weathering; sandy concretions 3 inches to 1 foot in diameter, up to 6 inches thick. Laminated sandstone beds at base, about 1 foot thick, contain plant-stem fragments. Sharp basal contact	14	161
5	Sandstone, medium grey, light grey weathering, rusty coloured in places, fine to medium grained, quartzose with 30% rusty and black grains, porous, very hard, medium to thick bedded; pebbly layers common near base, contain shale clasts	22	147
4	Shale, silty, brown, brownish grey weathering, weathers into brittle chips and flakes	9	125
3	Covered interval. Slope debris suggests mudstone and minor sandstone	66	116
2	Silty shale (80%) and sandstone (20%) interbedded; shale is brownish black, brownish grey weathering, silty, contains abundant brown matter, weathers to brittle chips and flakes; sandstone is fine grained, micaceous, laminated, in very thin, discontinuous beds up to 1 inch thick. Gradational contact with Unit 1	11	50
1	Mudstone, silty (60%) and interbedded sandstone (40%); mudstone is dark brown, grey weathering, massive, chunky, recessive relative to sandstone beds which are irregular in part, graded in part, and up to 1 foot thick; sandstone is fine grained, micaceous, quartzose, lithic, argillaceous, laminated	39	39
	Covered interval, about 20 feet thick, contains contact with Boundary Creek Formation.		

Section 3. Type section of mudstone member, Tent Island Formation, located on steep bluffs of Big Fish River for a distance of 5 miles between the confluence of Boundary and Little Fish (Cache) Creeks. Composite section consists of several partial sections measured by T. P. Chamney and F. G. Young. Stratigraphic separations between partial sections determined graphically from field measurements, photographs, and maps. Aerial photograph A14361-47; top of section at photo co-ordinates X=+1.45 cm, Y=+1.30 cm; base of section at top of Section 2.

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	Overlying beds: sandstone of Moose Channel Formation.		
	UPPER CRETACEOUS		
	Tent Island Formation		
	Mudstone member (2,803±140 feet)		
37	Sandstone (50%) and interbedded shale (50%), poorly exposed, inaccessible, medium bedded; shale is dark red-brown weathering, medium grey; sandstone contains abundant carbonaceous particles on bedding surfaces	42	2,803
36	Shaly mudstone, poorly exposed in part, covered in part, forms recessive slopes; coal lenticles up to 1/2 inch thick commonly intercalated with yellow sandy clay and grey clay; upper 5 feet contain sandstone beds and carbonaceous shale	78±5	2,761
35	Sandstone (50%) and interbedded shale (50%) in beds 0.1 to 1.5 foot thick, alternating, with sharp basal contacts; sandstone is greenish grey, medium grained, quartzose and lithic, with scattered chert pebbles, laminated with coarse-grained and carbonaceous plant-debris layers; minor calcareous concretions and pebble-conglomerate lenses	57	2,683
34	Conglomerate, pebbly, sandy matrix, largest phenoclast approximately 50 mm in diameter; sharp, eroded contact on underlying beds	0.6	2,626
33	Sandstone and interbedded shale, minor, brown, thin to medium bedded; sandstone is greenish grey, medium grained	2.2	2,625.4
32	Conglomerate, pebbly to cobbly; sand matrix is very coarse grained, chert-lithic; phenoclasts include fragments of quartz, porcellaneous chert, jasperoid, and green granodiorite. Largest clast is 210 mm in longest diameter	0.5	2,623.2
31	Sandstone, greenish grey, pale greenish grey weathering, fine to medium grained with rare pebbles and lenses of pebbly conglomerate; one massive bed, laminated, sharp basal and upper contacts	5.0	2,622.7
30	Marlstone, medium brown-grey, orange weathering, cryptocrystalline; one bed which grades laterally into interbedded shale and marlstone in one direction, and into limy, concretionary sandstone with coaly mudstone lentils in the opposite direction	1.5	2,617.7

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
29	Sandstone, medium yellow-grey weathering, mainly fine to medium grained, with coarse-grained bands and pebbly conglomerate layers, the latter containing carbonized wood fragments; bedding planes show oscillation ripple-marks and mud-cracks	5.2	2,616.2
28	Interval not examined, appears from a distance to be mainly light brown weathering mudstone; visual and graphic estimates of thickness agree	100±10	2,611
27	Mudstone, medium grey, soft, forms top of large eroded bank on northwest side of Fish River	60	2,511
26	Mudstone, medium grey, with yellow sulphurous bands and minor sand laminae, fine grained; small lens of weakly consolidated pebble-conglomerate near top, cemented by jarosite and/or sulphur	30	2,451
25	Mudstone, light grey weathering, poorly stratified, contains thin laminations of coal and sand, lenticular, yellowish grey weathering	120	2,421
24	Lower slope of bank covered by fine chips of orange-weathering mudstone	140	2,301
23	Covered interval. Calculated stratigraphic interval to top of next exposure downsection	350±35	2,161
22	Claystone, shaly, medium grey, with thin beds of sand in basal 2 feet	13	1,811
21	Siltstone, pale yellow weathering, dark grey, laminated, one lenticular bed	1	1,798
20	Alternating claystone and sand interbeds, very thin to thin bedded, claystone is brittle in part, with fragmental plant debris laminae, olive-yellow weathering. Lower contact gradational	28	1,797
19	Claystone (60%) and interbedded sand (40%); claystone is light grey in part, and in part brittle, ferruginous, brown-grey; beds less than 1 inch thick; sand is yellow-grey weathering, fine to medium grained, parallel laminated, in part cemented, in beds up to 8 inches thick, some carbonaceous plant debris laminae; unit has variegated and banded appearance	10	1,769
18	Shale, light grey, clayey, soft, stratified, orange banded; 20% sand interbeds, parallel laminated, 1 to 2 inches thick, fine to coarse grained, quartz-chert arenite, contain carbonaceous laminae	42	1,759
17	Covered interval. Partial section below measured one mile upstream. Calculated thickness of missing section	120±12	1,717
16	Shale, medium grey, with rare limy beds, pale orange-grey weathering, up to 0.5 foot thick, and silty, very fine grained sandstone beds, thin to medium bedded, lenticular in basal 10 feet	76	1,597

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
15	Shale, medium grey, poorly stratified, brittle, flaky, with minor argillaceous silty limestone beds, less than 1 inch thick, commonly displaying cone-in-cone structures	64	1,521
14	Shale, purplish brown-grey, semi-brittle, platy to flaky, with rare sandy siltstone beds, banded, and thin calcareous siltstone beds, commonly displaying cone-in-cone, shallow load-casts, and grooves	110	1,457
13	Mudstone, medium grey, thin bedded, chunky fracturing; rare siltstone beds, soft; poorly exposed	120	1,347
12	Mainly covered interval; thickness determined by graphic means; underlying section measured and described by T. P. Chamney (CR6A-71)	500±50	1,227
11	Shale, green-grey, silty, non-calcareous, with minor siltstone beds, 3 to 6 inches thick at the top, displaying cone-in-cone structure	10	727
10	Mudstone, rusty brown weathering, grading into green-grey at top; common 2-inch thick siltstone beds spaced about 5 feet apart, cone-in-cone structure common on bases of siltstone beds	30	717
9	Shale, grey, hard, silty, with common 2- to 3-inch thick, flinty, calcareous siltstone beds spaced 5 to 10 feet apart and displaying cone-in-cone structure	240	687
8	Shale, grey, hard, sharp platy fracture, cliff-former, inaccessible	30	447
7	Shale, grey, hard, silty, with scattered 2-inch thick siltstone beds	100	417
6	Shale, grey, relatively less indurated and silty, with 2-inch thick siltstone beds spaced about 5 feet apart	40	317
5	Shale, grey, hard, silty, flinty fracture	20	277
4	Shale, grey to pale brown, indurated, alternating with softer, crumbly shale; indurated shale contains 3-inch thick concretionary lenses; minor 3-inch thick calcareous siltstone beds present near base and top	100	257
3	Covered interval. Visual estimate	30±6	157
2	Shale, medium grey, grey-brown weathering, contains scattered chert pebbles. Visual estimate	100±20	127
1	Shaly mudstone, dark brown, silty, chunky, with thin, discontinuous sand lenses (5%), dark grey, fine grained, laminated, 1 inch thick	27	27
	Underlying beds: Cuesta Creek Member.		

Section 4: Type section of basal sandstone member, Moose Channel Formation, Big Fish River, N.W.T., downstream from confluence with Little Fish (Cache) Creek at Lat. 68°33'01"N, Long. 136°15'30"W. Measured by F. G. Young during high-water runoff stage in June 1970. Aerial photograph A14361-46, top of section at photo co-ordinates X=+4.30 cm, Y=+1.20 cm; base of section at photo co-ordinates X=-1.73 cm, Y=-5.11 cm.

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	Overlying beds: siltstone and shale of Ministicoog Member, Moose Channel Formation.		
	UPPER CRETACEOUS (MAASTRICHTIAN)		
	Moose Channel Formation		
	Basal sandstone member (1,959±100 feet)		
52	Sandstone, very fine grained, silty, orange-brown weathering, flaggy, poorly exposed; uneven shaly intercalations, ripple-marks	40	1,959
51	Sandstone, fine to coarse grained, thick bedded, interbedded with thinly bedded, friable, shaly, fine-grained sandstone in about equal proportions; light brown-grey pebbly layers and pebble conglomerate beds, 1 to 2 feet thick; common shallow-dipping, medium-scale cross-stratification	58	1,919
50	Sandstone, pale brown-grey, medium to coarse grained, slightly pebbly, beds 4 inches to 3 feet thick; interbedded minor shaly sandstone; rare pebble conglomerate beds with phenoclasts of maximum diameter of 170 mm; series of thin fining-upwards cycles, 2 to 5 feet thick, with sharp basal contacts	82	1,861
	Moved upstream about one-half mile. Approximately continuous partial sections from graphic calculations.		
49	Sandstone, fine to medium grained, interbedded with laminated siltstone and friable, shaly sandstone, medium grained; rare pebble layers; ripple-marks common; poorly exposed	30±10	1,779
48	Sandstone, fine to medium grained, light brown-grey; beds 1 to 5 feet thick, lenticular; 20% conglomerate in pod-like beds and interfingering with sandstone, in part scour-fillings in scours up to 10 feet deep	35	1,749
47	Covered	40	1,714
46	Sandstone, mainly fine to medium grained, rare pebbles, becomes partly coarse grained in upper 3 feet with shallow cross-stratification in various orientations; interbedded friable, platy sandstone common; minor ripple-marks and small worm-burrows; poorly exposed	58	1,674
45	Sandstone, medium grained, moderately sorted, coarse- to very coarse grained bands, pebbly in part, light brown-grey; feldspathic quartz-chert-slate litharenite; shallow cross-stratification with gently scoured basal surfaces	57	1,616
44	Covered, not measured directly	25 (approx.)	1,559

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
43	Sandstone, medium to coarse grained, pebbly, thick bedded; interbedded with recessive, covered rock, possibly mudstone in part	20.5	1,534
42	Conglomerate, pebbly, most pebbles less than 50 mm in diameter, in very coarse sand matrix, well consolidated; sharp basal contact, upper contact covered	1.5	1,513.5
41	Sandstone, pale grey, fine grained, scattered pebbles and cobbles; minor shallow cross-stratification, uniform	20	1,512
40	Covered, recessive slope	38	1,492
39	Sandstone, pale grey, pale greenish grey weathering, medium grained, pebbly; interbedded brown shale in upper 5 feet; feldspathic quartz-chert-slate litharenite; load-casts with current lineations and burrows on undersurfaces of beds	21	1,454
38	Covered, recessive slope	26	1,433
37	Sandstone, fine to medium grained, uniform, thin to medium bedded, flaggy weathering; minor cross-stratification	7	1,407
36	Mainly covered, recessive, probably mostly shale. Basal conglomerate about 1 foot thick rests with erosional contact on resistant sandstone bed at top of Unit 35	10	1,400
35	Sandstone, pale brown-grey, medium grained with scattered very coarse grains and pebbles, laminated, massive, irregularly fractured; minor orange-weathering pebble conglomerate beds, 0.5 to 1.0 foot thick in upper half, forming basal parts of medium- to large-scale cross-stratified sandstone beds	66	1,390
34	Sandstone, light grey, fine to coarse grained, pebbly, thick bedded; minor intercalated sandy, soft shale, whitish grey, coal seamlets, and pebble conglomerate; woody plant fragments and comminuted carbonaceous plant debris on bedding surfaces	15	1,324
33	Covered	6	1,309
32	Sandstone, medium grained, resistant, ripple-marks at top, cross-stratified; base is bioturbated; beds 2 to 4 feet thick	10	1,303
31	Shale, dark grey, very recessive, 60%, beds 1 to 3 feet thick, interbedded with sandstone, as below	15	1,293
30	Sandstone, medium grained, poorly sorted, pebbly to cobbly layers, shale-coated bedding planes with rootlets; recessive, thin bedded, minor friable sand layers and conglomerate	12	1,278
29	Sandstone and interbedded shale, beds 1 inch to 1 foot thick, conglomerate layers near top with maximum phenoclast diameters 250 mm	12	1,266
28	Conglomerate, compact, poorly sorted, dominated by quartzite and chert phenoclasts; sharp basal contact without obvious scouring; maximum diameter of clasts 130 mm	1	1,254

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
27	Sandstone, pale brown-grey, very fine to medium grained, thin bedded, laminated, carbonaceous streaks minor, soft-sediment slumped; minor conglomerate and scattered pebbles in sandstone	65	1,253
26	Shale and sandstone interbedded, recessive, mainly covered; shale, medium grey, interlaminated with siltstone, platy, medium brown; sandstone, medium grained, yellow, thin bedded; numerous rootlets	19	1,188
25	Sandstone, greenish grey weathering, light grey, fine to coarse grained, with scattered pebbles and pebble layers up to 1 foot thick; common tabular cross-stratification, medium-scale, in part comprising laterally accreted beds; upper 10 feet consist of soft, medium- to coarse-grained sandstone with plant fragments overlain by a massive, resistant sandstone bed; sandstone is feldspathic (10%) quartz-chert-slate litharenite	111	1,169
24	Covered, recessive interval, not measured directly	55	1,058
23	Sandstone, pale grey, medium to coarse grained, pebbly, relatively resistant, medium to thick bedded; minor beds, 1 foot thick, of compact pebble conglomerate, rusty weathering; in part cross-stratified, contains large coalified masses	90	1,003
22	Mudstone, medium grey, chunky fracturing, recessive	15	913
21	Sandstone, light greenish grey, orange weathering, coarse to very coarse grained, pebbly, minor medium grained, slightly calcareous; thick bedded to massive, resistant; medium-scale cross-stratification, carbonized woody impressions	50	898
20	Sandstone, green, fine grained, irregularly fractured, slabby, relatively recessive; minor mudstone, medium grey, dark red-brown weathering in beds to 1 foot thick; minor conglomerate, pebbly to cobbly, in beds 6 inches thick	20	848
19	Sandstone, pale grey, fine to coarse grained, moderately sorted, thick bedded to massive, resistant; poorly preserved leaf impressions and carbonized films common, minor flow-rolls up to 2 feet in diameter; minor compact pebble conglomerate in 1-foot beds; cemented burrows at base; above 1-foot thick basal conglomerate	70	828
18	Shale, mainly covered, recessive	10	758
17	Sandstone, medium grey, coarse grained, granular to pebbly, massive, resistant; tabular cross-stratification in sets up to 6 feet thick and in reversed orientations; small-scale trough cross-stratification at tops of beds; rare beds of conglomerate and mudstone	83	748
16	Recessive, mainly covered interval. Probably shale, sandstone, and unconsolidated sand interbeds	10	665

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
15	Sandstone, pale brown-grey, medium to coarse grained, granular to pebbly, thick bedded to massive, minor sandy shale intercalations; common tabular cross-stratification	25	655
14	Mainly covered interval, recessive; partly platy fracturing, fine-grained sandstone	22	630
13	Sandstone, light yellowish grey weathering, medium to coarse grained, massive, resistant, rare cobbles and scattered pebbles within sandstone; cross-stratified in part; feldspathic quartz-volcanilithic-chert litharenite	74	608
12	Sandstone, orange weathering, medium grained, and minor conglomerate; clay films on bedding surfaces	3	534
11	Sandstone, pale green-grey, pebbly, moderately sorted, alternating fine- and coarse-grained bands, minor thin conglomerate beds; thick bedded to massive, medium-scale tabular cross-stratification forming beds of lateral accretion; coalified tree stumps and woody fragments; numerous shallow scour-and-fill structures	33	531
10	Covered by talus	30	498
9	Sandstone, pale green, medium grained, thick bedded to massive, irregular slabby fracturing; occasional pebble conglomerate beds	20	468
	Moved upstream about one-half mile; base of above partial section approximately same stratigraphic level as top of underlying partial section.		
8	Sandstone, medium yellow weathering, largely inaccessible, thick bedded, fairly uniform-appearing, minor shale and conglomerate interbeds	88	448
7	Mudstone, medium grey, and interbedded sandstone (40%), pale yellow-grey weathering, mainly thin bedded	17	360
6	Sandstone, pale green-grey weathering, thick and even bedded, becomes increasingly resistant upsection; minor conglomerate beds, up to 2 feet thick	15	343
5	Interbedded sandstone and shale, relatively recessive, inaccessible, grades laterally into dominantly sandstone	10	328
4	Sandstone, fine grained(?), granular, apparently uniform texture throughout, medium to thick bedded, inaccessible at close range	45	318
3	Interbedded sandstone and shale in about equal proportions, sandstone pale green-grey weathering, medium bedded to massive, inaccessible	25	273
2	Sandstone, light grey, medium to coarse grained, thick bedded; tabular cross-stratification common; coaly fragments common up to 1 foot long	40	248

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
1	Sandstone, green-grey weathering, mainly medium grained, with minor coarse- and very coarse grained bands; minor 6-inch thick shale beds in basal 15 feet; medium to thick bedded, rare shallow cross-stratification; scattered pebbles and rare pebble conglomerate lenses and beds; feldspathic quartz-chert-lithic arenite	208	208
	Underlying beds: Tent Island Formation.		

Section 5: Type section of Ministicoog Member, Moose Channel Formation, on Big Fish River, N.W.T., immediately west of Mackenzie Delta. Uppermost 250 feet of formation not present. Top of section located at Lat. 68°37'50"N, Long. 136°08'20"W. Measured by F. G. Young, June, 1970, with addenda supplied by T. P. Chamney who measured and sampled section in 1971. Aerial photograph A14361-46, top of section a photo co-ordinates X=+6.68 cm, Y=+7.10 cm; base of section at photo co-ordinates X=+4.30 cm, Y=+1.20 cm.

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	Overlying beds: Pleistocene(?) sand, fine to medium grained, ripple-laminated, and cobbly gravel, approximately 40 feet thick.		
	UPPER CRETACEOUS		
	Moose Channel Formation		
	Ministicoog Member (973±45 feet)		
29	Sandstone, sandy shale, and shale, thinly interbedded with rare beds, 2 feet thick, of sandstone and pebbly conglomerate. Sandstone, fine grained, orange weathering, in part convoluted, cross-laminated, carbonaceous; quartzose chert litharenite; shale, medium grey, about 50% by volume	86	973
28	Mudstone, medium grey, recessive, with minor medium- to coarse-grained sandstone beds, cross-stratified	28	887
27	Mudstone and interbedded siltstone (40%), thin to medium bedded, ripple laminated; unit capped by thick bed of cross-stratified sandstone, flaggy fracturing, yellow-grey weathering	45	859
26	Shaly mudstone and minor siltstone, brown, thin bedded; poorly exposed, abundant slope debris	50	814
25	Covered	10	764
24	Small scattered outcrops of shale with thin interbeds of siltstone and silt laminations	20	754
23	Covered, recessive and slumped slopes	70	734
	Moved one mile south to high, east bank of river.		

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
22	Mudstone, yellow-grey, light yellow-grey weathering, very thin to medium bedded; minor siltstone, thin bedded, in part carbonaceous, fragmental	76	664
21	Sandstone, medium grained, lenticular, rare pebbles and coaly wood fragments, common sets of climbing ripple-marks, common thin interbeds of shaly sand, recessive	10	588
20	Sandstone, pale yellow-grey weathering, medium to coarse grained, moderately sorted, thick bedded, festoon cross-stratification; irregular shaly interbeds uncommon; unit appears to thicken northwestward; sharp lower contact	19	578
19	Shale (80%) and platy siltstone interbeds (20%), brown-grey weathering, recessive	23	559
18	Sandstone, brown-grey weathering, very fine grained, deformed into ball-and-pillow structures, and shale (50%), yellow-grey	6	536
17	Siltstone and shale, 50% each, interbedded, medium bedded; rare lenticular beds of sandstone up to 1.5 feet thick, contorted, laminated, fine grained	5	530
16	Siltstone (80%), brown-weathering, argillaceous, micaceous, irregularly splitting, current lineations and sole-marks; and interbedded mudstone, brown-grey; rare yellow and grey claystone with nodular coal	18	525
15	Shale, medium grey, rare siltstone bands; white efflorescent marker horizon 2 feet above base	13	507
14	Siltstone (50%) and interbedded shale (50%)	15	494
13	Shaly mudstone, very thin to thin bedded	15	479
12	Shaly siltstone (50%) interbedded with and in part grading into silty shale (50%), dark grey, soft; macerated carbonaceous debris common on bedding surfaces. Base of unit ties in approximately with top of pyramid-like hill one mile southwest	10±10	464
11	Mudstone, grey, with thin interbeds of siltstone, evenly laminated, burrowed, load-casts, in part olive to orange weathering; chunky mudstone predominates	110	454
10	Siltstone, medium grey, thin to medium bedded, parallel and cross-laminated; minor interbedded clay, yellow and grey	12	344
9	Mudstone, dark grey, chunky fracturing, minor siltstone interbeds	10	332
8	Covered	70±10	322
7	Interbedded soft friable sandstone and hard sandstone; minor soft shale; brown, silty, friable sandstone up to 5 feet thick in one bed near base; overlying beds thin to medium bedded; occasional pebbly layer	15	252

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
6	Sandstone, brown-grey weathering, medium to thick bedded, lenticular shale partings common; sandstone mainly fine grained, lithic, laminated, moderately sorted; erosive, sharp basal contact	10	237
5	Silty sandstone, light grey, very fine grained, thin to medium bedded, laminated; approximately 20% soft shale interbeds, grey; some very lenticular, cross-stratified sandstone beds	15	227
4	Sandstone, single resistant bed, conglomeratic along basal contact, fine to medium grained, laminated, medium-scale cross-stratification; minor discontinuous, thin ferruginous mudstone layers	4	212
3	Interbedded sandstone (60%), very fine grained, and mudstone, thin bedded, light grey; sandstone is evenly laminated and cross-laminated with rare coarse-grained and pebbly layers	5	208
2	Covered, recessive; calculated thickness. Moved south one mile to east bank at top of type section of Moose Channel Formation	75±25	203
1	Mudstone, medium grey, silty in part; rare siltstone and silty, very fine grained sandstone beds, evenly laminated, micaceous	128	128
	Underlying beds: basal sandstone member (Section 4).		

Section 6: Type section of Aklak Member, Reindeer Formation, as well as top of underlying Moose Channel Formation, measured on lower course of Aklak Creek which discharges into the southern end of Coal Mine Lake, northwestern Mackenzie Delta. Strata are exposed only locally on 200-foot high bluffs, and extensive covered or semi-exposed stratigraphic intervals were measured graphically using aerial photographs and 1:50,000-scale map. Base of section is at Lat. 68°40'06"N, Long. 136°21'00"W, uppermost exposed beds are located at Lat. 68°40'51"N, Long. 136°19'00"W. Lower half of section measured by D. H. McNeil and T. P. Chamney in 1971, upper half by F. G. Young in 1972. Aerial photograph A14361-44; top of section at photo co-ordinates X=-4.05 cm, Y=+2.70 cm, base of section at photo co-ordinates X=-5.72 cm, Y=+0.15 cm.

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	LOWER TERTIARY OR UPPER CRETACEOUS		
	Reindeer Formation		
	Aklak Member (1,800±60 feet)		
	Overlying beds: covered, higher beds of Reindeer Formation.		
51	Broken debris only; shale, black, in part dark grey, leaf impressions, carbonaceous, flaky	15	1,798
50	Covered; scree slopes suggest mainly brown-grey silty mudstone	40	1,783

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
49	Sandstone, light bluish grey, medium grained, argillaceous, semi-friable, chert litharenite; mainly broken, flaggy debris; broken clay-ironstone nodules near top	45	1,743
48	Vegetated and covered interval	92	1,698
47	Mudstone, light red, hematitic, abundant plant impressions, chippy, hard debris mainly; in part scoriaceous, dark bluish grey cinder debris; dark grey mudstone at top with leaf impressions	13	1,606
46	Vegetated and debris-covered, recessive slope	90±5	1,593
45	Sandstone, medium grey, medium- to coarse-grained chert litharenite, pebbly in part, thin to thick bedded; in part tabular cross-stratification	15	1,503
44	Covered interval	20	1,488
43	Mudstone, dark brown-grey to black, carbonaceous to coaly, abundant leaf and stem impressions, coal laminae (5%) common in basal 20 feet; thin to medium bedded; chippy to flaky weathering	40	1,468
42	Sandstone, yellowish grey weathering, medium to coarse grained, ripple-marked surfaces, mainly broken slabs	10	1,428
41	Covered interval; fragmental sandstone debris common	20	1,418
40	Sandstone, orange weathering, medium grained; feldspathic chert litharenite, parallel laminated, dark grey bands, ripple laminated in part, fairly well sorted	8	1,398
39	Conglomerate, friable, sandy, poorly exposed	2	1,390
38	Interbedded siltstone and silty mudstone with minor thin coal seams; siltstone is partly yellow, partly red, contains leaf, stem, and fruit fossils, beds 1 to 3 inches thick; mudstone oxidized to yellow, red, and black tones, becoming scoriaceous and cindery towards top (ancient bocanne)	72	1,388
37	Interbedded clay, mudstone, ochrous marlstone, and coal; mud is soft, yellowish grey; coal is shaly, beds 2 inches thick; very easily eroded	7	1,316
36	Conglomerate, pebbly to granular, slightly friable in basal 2 feet, overlain by bed, 5 feet thick, of pebbly "grit" with sand lenses, rich in chert and white quartz. Sharp upper contact	8	1,309
35	Covered by scree; probably mainly coaly mudstone	60	1,301
34	Sandstone, medium to coarse grained, pebbly layers, thick bedded, with 6-inch tabular cross-stratification sets dipping northeast; becomes thin bedded and flaggy towards top. Base not exposed	15	1,241
33	Interval largely poorly exposed, apparently underlain mainly by sandstone, medium grained to granular, pebbly in part, chert litharenite	300±30	1,226

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
32	Covered interval, recessive slope-former; debris indicates mainly grey shale	75±5	926
31	Siltstone, silty shale, and rare silty limestone interbedded, mainly orange-grey to red; broken outcrops on grassy, recessive slope	45	851
30	Interbedded red siltstone and silty mudstone, rootlet and leaf impressions present; poorly exposed, mainly broken debris	75	806
29	Fragmental debris of light red, orange, and bluish black siltstone and mudstone; in part coaly, some of which is sintered to cindery or scoriaceous material; in part brecciated (ancient bocanne)	23	731
28	Seat earth, unlithified, brownish grey, overlain by 6-inch thick coal seam, friable	2	708
27	Sandstone, grey, fine grained, well sorted, irregularly fractured	2	706
26	Sandy siltstone and mudstone, interbanded, brown-grey, poorly exposed	33	704
25	Broken outcrop of red-weathered and oxidized siltstone, mudstone and silty sandstone; fresh surfaces light to dark grey; scoriaceous and cindery fragments common	20	671
24	Sandstone, medium grained, laminated, rusty banded by silt and coalified plant-fragment debris	1	651
23	Covered by comminuted rock fragments. Possibly underlain by medium brown silty mudstone	39	650
22	Mainly scree covered; black shale and coal present under debris	25	611
21	Covered, recessive slope; burrow-tailings reveal abundant black shale and coal; possible sandstone bed in middle, very fine to fine grained, parallel laminated, coal fragmental	25	586
20	Interbedded conglomerate and sandstone, soft and friable, thin bedded, poorly exposed	6	561
19	Sandstone, medium to very coarse grained, granular to pebbly in part, vaguely laminated, coal fragmental, laminae abundant; becomes increasingly softer upwards	6	555
18	Conglomerate, pebbly to cobbly, very poorly sorted, coarse sand to pebble matrix, and sandstone, coarse grained, coal fragmental, as lenses and interbeds which grade rapidly laterally into conglomerate; phenoclasts rounded, heterogeneous composition, maximum diameter of 300 mm	8	549
17	Conglomeratic sandstone, massive, resistant, conglomerate layers and lenses (10%)	29	541

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
16	Alternating conglomerate and sandstone beds, 0.5 to 1.0 foot thick; conglomerate is grey, pebbly to cobbly, polymictic, with medium- to coarse-grained sand matrix, and grades abruptly laterally into sandstone; sandstone is speckled grey, in part rusty weathering, medium grained, poorly sorted, pebbly, chert-quartz arenite, in part cross-stratified	9	512
15	Partly covered interval with broken outcrops of red-weathered siltstone, silty sandstone and silty shale, grey to light red; ripple cross-laminations and parallel laminations common; well-preserved leaf impressions on some bedding surfaces	55	503
14	Siltstone, rusty grey, bright red weathering, quartzose, abundant rusty grains, laminated and cross-laminated, platy weathering	12	448
13	Covered, recessive slope	20	436
12	Sandstone, medium brown-grey, light orange-grey weathering, fine grained, micaceous quartz-chert arenite, carbonaceous debris, root burrows, thin bedded, ripple cross-laminated in part; minor mudstone interbeds, 1 to 3 inches thick	11	416
11	Mudstone, brown, weathers greyish brown, massive, weathers into angular, hard chunks	19	405
10	Coal, black, varies from dusty and ?argillaceous to shiny and brittle, sub-bituminous, yellow to black weathering; moderately resistant, thin to medium bedded. Sharp contact on sandstone	12	386
9	Sandstone, medium grey, weathers light brown-grey, fine grained, subangular quartz, chert, and lithic grains, laminated, thin bedded; base not exposed	8	374
8	Covered interval	170±20	366
7	Sandstone, dark grey, medium grained, beds 1 to 3 feet thick, tabular cross-stratification, ripple-marks on some bedding planes	11	196
6	Sandstone, medium grey, weathers rusty grey, fine grained, porous, almost friable, quartz-chert arenite, climbing ripple-laminations, splits into slabs, 1 to 3 inches thick	37	185
5	Sandstone, dark grey, weathers medium grey to rusty, medium grained, poorly sorted, subangular, slightly porous, quartz-chert-carbon-lithic arenite, slightly micaceous; large cross-stratification sets, low to high angle, in beds 2 to 3 feet thick; pebble-conglomerate at base sharply overlies mudstone below	7.5	148
4	Mudstone, brownish black, grey-brown weathering, silty, micaceous, carbonaceous, with rare 2-inch thick siltstone beds, laminated; becomes shale downwards, dark brown, dark grey weathering, soft, fissile	29.5	140.5

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
3	Coal, black, weathers rusty brown, black, and greenish black, lignitic, hard, contains plant fragments, top 4 feet are flaky; indurated lenses of coaly claystone, brownish black, relatively soft, about 25% of unit, forms "eyes" and lenses up to 10 feet long; base not exposed; pollen and spore assemblage suggests Maastrichtian or ?early Paleocene age (W. W. Brideaux) (GSC loc. C-11299)	23	111
2	Pebbly sandstone, medium grey, weathers rusty to light brown-grey, medium grained, poorly sorted, subangular, quartz-chert-lithic arenite, resistant, beds 4 inches to 2 feet thick	6	88
1	Sandstone, rusty grey, fine to medium grained, black and rust speckled, tight, hard, laminated, thin bedded, low-angle cross-stratification common, convoluted beds near base, ripple-marks present	82	82
	UPPER CRETACEOUS (MAASTRICHTIAN)		
	<u>Moose Channel Formation</u>		
	Ministicoog Member (incomplete; 392 feet)		
18	Covered interval	29	392
17	Mudstone (80%), brownish black, silty, hard; interbedded siltstone and rare laminated sandstone, in part lenticular, maximum bed thickness 3 feet	20.5	363
16	Siltstone (70%) and interbedded mudstone (30%); medium-scale low-angle cross-stratification set, truncated at top	2.5	342.5
15	Mudstone (70%), brownish black, and interbedded sandstone (30%), greyish black, leaden grey weathering, fine grained, quartz-chert arenite, minor pebbles and cobbles, lenticular beds	6	340
14	Siltstone, sandy, medium grey, weathers light brown-grey, silt to fine grained, quartzose, black minerals 15%, cross-laminated beds alternate with parallel laminated beds about 1 foot thick	4	334
13	Mudstone (70%) and sandy siltstone (30%) interbedded; mudstone is brownish black, weathers medium brown-grey, silty, hard, beds 3 inches to 3 feet thick	15	330
12	Sandstone, medium grey, black and white speckled, weathers light brown, fine to medium grained, grains subangular to subrounded, porous, hard, laminated, thin to medium bedded, small-scale cross-stratification, ripple-marks, resistant	10	315
11	Covered interval	150±15	305
10	Sandstone, speckled, weathers light orange-grey, quartz-chert arenite, medium to coarse grained with pebbles at top (coarsens upwards), poorly sorted; appears massive, unstratified	15.5	155.5

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
9	Covered interval	23.5	140
8	Sandstone, medium grey, fine to medium grained, pebbly, quartz-chert arenite, poorly sorted, cross-stratified, parallel laminated, contains conglomeratic lenses up to 5 inches thick, quartzite and chert pebbles and cobbles, well rounded	2.5	116.5
7	Covered interval	7	114
6	Sandstone, rusty medium grey, speckled, porous, hard, ripple-marks, low-angle cross-stratification, laminated, thin bedded, resistant	5	107
5	Mudstone (60%) and interbedded sandstone (40%); mudstone, chippy to chunky fracturing, as below; sandstone, medium to dark grey, weathers brown-grey, quartz-chert arenite, very fine to fine grained, laminated and cross-laminated, sharp bedding contacts	5	102
4	Covered interval; probably underlain by shale	22	97
3	Shale, brownish black, dark brownish grey weathering, fissile, with minor (10%) siltstone beds, lenticular, discontinuous, thin, dark grey, compact	20.7	75
2	Pebbly mudstone, unconsolidated, leaden grey, polymictic, unsorted, pebbles and cobbles up to 6 inches in diameter randomly disposed in clay matrix; sharp contact on underlying unit	0.3	54.3
1	Siltstone (50%) and interbedded mudstone (50%), evenly alternating; siltstone is dark grey, hard, non-porous, laminated, in beds up to 1 foot thick, with some low-amplitude ripple-marks; mudstone is brownish black, silty, hard, chunky, relatively easily eroded	54	54
	Formation is exposed sporadically in short intervals below here; basal contact and stratigraphic thickness uncertain.		

Section 7: Partial section of Moose Channel Formation measured near mouth of Eagle Creek, northern Yukon Territory, in right (east) bank where beds are reasonably well exposed and strike northward, dipping 30 to 50° easterly. Aerial photograph A15462-23; Lat. 68°45'N, Long. 136°34'W. Measured by F. G. Young in June, 1971.

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	Top of section not exposed; possible fault between here and next partial section upstream.		

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	UPPER CRETACEOUS (MAASTRICHTIAN)		
	Moose Channel Formation		
	Ministicoog Member (235+ feet)		
51	Mudstone, grey, mainly silty, brittle; minor silt laminae, bands, and very thin beds (5-10%); siltstone is light grey, orange weathering, laminated, micro-cross-laminated in part	106	1,515
50	Silty shale, medium to dark grey, with rare thin beds of argillaceous siltstone, laterally continuous	10	1,409
49	Mudstone, light to medium grey, chunky, poorly stratified, scattered yellow nodules and rare pebbles and carbonaceous fragments; minor graded beds of sandstone up to 1 foot thick, sharp basal contacts with current lineations	40	1,399
48	Mudstone (75%), light grey and interbedded medium-bedded siltstone (25%), laminated, plant debris on bedding surfaces, rootlets	18	1,359
47	Mudstone, light grey, chunky, soft, with rare, scattered pebbles and small cobbles of chert and quartzite; almost unstratified; rare gypsiferous (weathered pyrite?) nodules	34.5	1,341
46	Interbedded soft shaly sandstone, sand, and light grey mudstone, recessive; sand is light brown, fine grained, carbon fragmental, in part ripple laminated. Sharp basal contact	5	1,306.5
45	Interbedded sandstone and shale; sandstone is fine to medium grained, in part granular to pebbly, crudely parallel laminated, slightly feldspathic chert-quartz arenite; shale contains abundant carbonaceous fragments, dark grey, in part sandy, evenly laminated	4.5	1,301.5
44	Silty and sandy mudstone, chunky, recessive, poorly consolidated, medium grey; rare black chert pebbles; minor sandy beds, parallel laminated, rich in carbonaceous debris	14	1,297
43	Sandstone, very argillaceous, fine to medium grained, medium to dark grey; uneven, medium bedded; bioturbated, minor chert granules and pebbles, comminuted plant debris in concentrated laminae	3	1,283
	Basal sandstone member (1,280±100 feet)		
42	Conglomerate, pebbly-cobbly, medium- to coarse-grained sandy matrix, grades laterally into sandstone, medium grained, chert-quartz arenite, ripple-and-dune structures, small fan-like feeding burrow on upper surface	4	1,280

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
41	Partly covered. Sandstone, light grey, very fine to fine grained, shale clasts common, minor pebble layers; thin to thick bedded; probable argillaceous sand interbeds	39	1,276
40	Sand, weathered outcrop, orange to grey, fine grained, argillaceous, minor coarse pebbles	7	1,237
39	Scree-covered slope. Scree fragments of very argillaceous, very fine grained sandstone, friable, chunky	3	1,230
38	Sandstone, light grey, mostly very fine grained, very thin to medium bedded, chert-quartz arenite	6	1,227
37	Sandstone, orange-brown weathering, very fine to fine grained, slightly argillaceous, chert-quartz arenite, medium to thick bedded, uniform. Thin bed of pebble conglomerate 2 feet below top	24	1,221
36	Partly talus-covered, recessive interval. Sandstone, shaly to platy fracturing, light grey, fine grained, parallel laminated, contains small shale chips	16	1,197
35	Sandstone, fine grained, relatively resistant, well bedded, with small lenses of conglomerate	22	1,181
34	Sandstone, fine grained, thick bedded, parallel laminated, carbonaceous fragments, small shale clasts, interbedded platy, friable sandstone	15	1,159
33	Sandstone, fine grained, medium to thick bedded, resistant, carbonaceous debris in parallel laminae, minor current lineations and cross-stratification, in part platy- to shaly-weathering interbeds	20	1,144
32	Sandstone, fine grained, medium to thick bedded, banded, slabby splitting in part, planar cross-stratification, minor ripple-laminated beds; a few surfaces exhibit simple and branching burrows	10	1,134
31	Sandstone, fine grained, resistant, less than 10% shaly sandstone interbeds; occasional pebbly beds containing granitoid clasts up to 140 mm in diameter	30	1,124
30	Sandstone, fine grained, slightly argillaceous, poorly to moderately sorted, lenses of conglomerate with phenoclasts up to 130 mm in diameter; minor shaly sandstone with foraging burrows and pebbles	20	1,094
29	Sandstone, fine grained, light grey, moderately to poorly sorted, interbedded shaly and friable sandstone, fine grained, carbonaceous debris; minor shale partings; rare shale-chip conglomerate layers, ripple-drift and planar cross-stratification, burrows in shaly sandstone, rare ball-and-pillar structure	55	1,074
28	Sandstone, fine grained and minor sand interbeds, platy and slabby, sandstone medium to thick bedded; ripple laminated in part, burrowed in part, *Rhizocorallium* feeding burrows, festoon cross-stratification in part	125±15	1,019

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	Uncertain contact relations; moved downstream to point near confluence of Hornet Creek entering on left side.		
27	Conglomerate, pebbly sandstone, mudstone, coal, thin to very thin interbeds, mostly oxidized. Sharp basal contact	2	894
26	Sandstone and sand interbedded, scattered pebbles and cobbles in thick beds, fine grained, chert-quartz arenite, parallel-laminated, low-angle planar cross-stratification; rare lenses of pebble conglomerate up to 1.5 feet thick; rare limonitic oxidized beds of sand	65	892
25	Interbedded sandstone, siltstone and mudstone, recessive; sandstone in part cross-stratified	10	827
24	Sandstone, light grey, very fine grained; thin to medium bedded, planar cross-stratification, mild scours	3	817
23	Poorly exposed grey shaly mudstone with interbedded fine-grained sandstone. Sharp basal contact	4	814
22	Conglomerate, pebbly with minor cobbles, poorly sorted, no visible imbrication. Erosional contact	5	810
21	Coaly shale, black, papery and flaky, contains leaf impressions including *Metasequoia cuneata* (GSC loc. C-11269)	2	805
20	Sandstone, light yellowish grey weathering, fine grained, chert-quartz arenite, carbonaceous fragments, medium to thick bedded, grades at top into unconsolidated sand with mud intercalations	15	803
19	Recessive, poorly exposed interval. Mudstone, clayey, medium grey, yellow stained, dark reddish brown weathering, minor pebbles and sandy bands and thin beds; minor olive-green argillaceous siltstone and dark grey bituminous bands	29	788
18	Sandstone, fine to medium grained, rare chert and quartz pebbles, moderately sorted, medium to thick bedded	7	759
17	Covered and recessive interval	10	752
16	Sandstone, fine to coarse grained, in part pebbly; parallel laminated and ripple laminated; contains sand and mudstone beds up to 1 foot thick	11	742
15	Poorly exposed mudstone with minor medium-bedded sandstone	10	731
14	Sandstone, very fine to fine grained, in part unconcolidated, parallel laminated, poorly exposed	5	721
13	Mudstone, recessive, mostly covered; minor sandstone	9	716

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
12	Sandstone, medium- and coarse-grained bands, conglomeratic layers and lenses with chert cobbles and orange-weathering rip-up clasts, parallel laminations; basal conglomerate 0.5 foot thick; sharp basal contact	23	707
11	Mudstone, silty, grading to siltstone, laminated, with coaly fragments	4	684
10	Sandstone bed, fine to medium grained, crudely laminated, feldspathic chert-quartz arenite	5	680
9	Mudstone, medium grey, thin bedded, with sandy bands and rare coal stringers; recessive; sharp basal contact	20	675
8	Sandstone, medium grained, granular to pebbly layers at bases of thick beds, faint laminations, minor sandy mud and medium-grey mudstone interbeds; abundant shale clasts, in part cross-stratified. Sharp, even basal contact	25	655
7	Mudstone, light grey, bedded, sandy layers, poorly exposed	19.5	630
6	Sandstone, shaly partings at base, becoming more resistant upwards; basal beds are pebbly, and contain shale clasts and large plant fragments; parallel laminations and minor planar cross-stratifications	4.5	610.5
5	Interbedded mudstone and sandstone, thin bedded, recessive	2	606
4	Sandstone, light grey, fine grained, slightly feldspathic chert-quartz arenite; thin to medium bedded; current lineations common, parallel laminated, carbonaceous debris laminae	8	604
3	Interbedded sandstone, argillaceous sand, and dark grey shale, thin to medium bedded; thicker beds of sandstone display ripple-drift cross-lamination sets, planar cross-stratification, and parallel lamination, and contain mud-clasts and plant stem fragments	26	596
2	No lower strata on east bank of creek. Calculated thickness of strata covered by creek bed to exposures on west bank	530±50	570
1	Sandstone, fine grained, in part convoluted, ripple-laminated; 5% conglomerate, minor ironstone concretions. Contact covered	40	40
	<u>Tent Island Formation</u>		
	Mudstone with 10% interbedded siltstone	250	
	Base of section exposed on lower Eagle Creek.		

Section 8: This composite section of the middle part of the Moose Channel Formation and basal Reindeer Formation was summarized from several shorter sections measured and described from bank exposures on the right side of Eagle Creek, Yukon Territory, at approximately Lat. 68°42'N, Long. 136°32'W, by D. H. McNeil and F. G. Young.

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	LOWER TERTIARY OR UPPER CRETACEOUS		
	Reindeer Formation		
	Aklak Member (664+ feet)		
	Overlying beds (upper part of formation) not exposed - thick, recessive interval.		
80	Interbedded sandstone and conglomerate, some conglomerate beds graded, others not, bedding contacts sharp, basal contact sharp and erosional	31	2,246.5
79	Covered interval	4	2,213.5
78	Sandstone, medium grained, lithic chert-quartz arenite, thick bedded, bedding contacts sharp, occasional conglomerate beds, 1 foot thick	13	2,209.5
77	Conglomerate, pebbly, with sandstone lenses common; sharp, uneven lower contact	12	2,196.5
76	Sandstone, as in Unit 78	10	2,184.5
75	Conglomerate, pebbles and cobbles in sandy matrix, maximum phenoclast diameter 20 cm, clasts well rounded; sandstone lenses about 1 x 20 feet; contain clasts of similar lithic sandstone, possibly of internal derivation; unit appears homogeneous except for indistinct horizontal orientation of pebbles	28	2,174.5
74	Covered interval	40	2,146.5
73	Sandstone, light grey, rusty grey weathering, medium grained, very poorly sorted, no visible porosity, quartz-chert-feldspar-muscovite composition; medium bedded, irregularly fractured, crossbedded in part; pebbly horizons common, minor scour structures filled with pebbles	108	2,106.5
72	Covered interval	8	1,998.5
71	Sandstone, medium to dark grey, fine grained, moderately sorted, porous, pebble layers common, thin to medium bedded, irregularly fractured; carbonaceous debris common on bedding planes; ripple-marks	67	1,990.5
70	Sandstone, as in Unit 69 but contains in addition few beds, 1 foot thick, of muddy, micaceous siltstone; coalified plant fragments and shale clasts common	7	1,923.5
69	Sandstone, medium grey, fine to medium grained, poorly sorted, minor porosity, hard, grains subangular to subrounded, quartz-chert arenite, pebbly bands common, coaly fragments common; thin to medium bedded, minor small- and medium-scale cross-stratification	63	1,916.5

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
68	Covered interval	50	1,853.5
67	Sandstone, light to medium grey, medium grained, very poorly sorted, subangular to subrounded, nearly friable, quartz-chert-feldspar arenite; thin to medium bedded, moderately resistant; large sets of cross-stratification in some beds, pebbly horizons common	90	1,803.5
66	Sandstone, medium to coarse grained, banded, minor pebble conglomerate and scattered pebbles; medium bedded with occasional thick beds	57.5	1,713.5
65	Conglomerate, cobbly, maximum clast-diameter 8 inches (21 cm)	1.5	1,656
64	Sandstone, medium to coarse grained, banded, with 10% conglomerate beds and pebbly sandstone beds, lenticular, up to 1 foot thick	27	1,654.5
63	Coal, black, bituminous	1	1,627.5
62	Sandstone, light grey, medium grained, poorly sorted, with minor conglomerate; thick bedded	30	1,626.5
61	Sandstone, light grey, rusty grey weathering, medium grained, poorly sorted, quartz and variously coloured chert, granular and pebbly, with 20% conglomerate beds, relatively continuous, 0.5 to 1.0 foot thick; medium to thick bedded; resistant; cobbles and coaly debris at base of unit which is partly convoluted; small- and medium-scale crossbedding up to 3 feet thick per set	14	1,596.5
	UPPER CRETACEOUS (MAASTRICHTIAN)		
	<u>Moose Channel Formation</u>		
	Ministicoog Member (1,080 feet)		
60	Mudstone, medium grey, recessive, coal laminae, silty and sandy in uppermost 1 foot, poorly stratified	11.5	1,582.5
59	Shale, black, papery, coaly, rare coal lenses, yellow weathering; leaf impressions common	3	1,571
58	Mudstone, medium grey, in part silty, with small clay ironstone concretions. Unit yielded recycled Early Cretaceous spores and pollen, early Paleozoic recycled spores, *Stereisporites antiquasporites* (Wilson and Webster) Dettmann, *Inaperturopollenites hiatus* (Potonié) Thompson and Pflug, *Betulacoeoipollenites* sp. cf. *B. infrequens* (Stanley) Norton and Hall. Age: Late Cretaceous, probably Maastrichtian (palynological analysis by W. W. Brideaux)(GSC loc. C-11285).	17.5	1,568
57	Sandstone, pale green-grey, orange-weathering mud-clasts, fine grained, laminated, macerated coaly plant debris, in part outline current lineations on parting planes; thick bedded	22	1,550.5

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
56	Interbedded sandstone and mudstone; sandstone dark green-grey, very fine to fine grained, even splitting, poorly consolidated, medium bedded; mudstone, chunky, irregular fracturing, medium grey, in beds up to 1 foot thick; recessive	12.5	1,528.5
55	Sandstone, fine grained, very evenly laminated, ripple laminated in part, abundant carbonaceous fragments, some large coalified wood fragments	7	1,516
54	Covered by vegetation on both banks of stream	100±10	1,509
53	Very poorly exposed sandstone, slabby, ripple-marked, with recessive interbeds of mudstone	100±10	1,409
52	Interbedded mudstone, grey, sandstone, partly pebbly, and pebble conglomerate, well cemented; sandstone bedding soles display load casts, fine crawling trails and pocket burrows	4	1,309
51	Conglomerate, bright yellow to orange, cobbly, with interbedded sand, olive-green, coarse grained, and sandstone, yellow weathering, fine grained; thin to medium bedded	4	1,305
50	Sandstone, yellowish grey weathering, coarse grained, pebbly, feldspathic quartz-chert arenite, carbonaceous laminae and coalified wood fragments, in part cross-stratified, thick bedded; pebbles consist of chert, chert-grit sandstone, ironstone	11	1,301
49	Recessive, mainly covered interval; in part shale, medium grey, coaly in part. Sharp basal contact	14	1,290
48	Sandstone, medium grained, well sorted, hematitic at top, pebbly to cobbly near base, with mixed conglomerate and sandstone filling 3-foot deep scour, sharp, eroded basal contact; resistant, massive	28	1,276
47	Sandstone, orange-grey weathering, medium grained, sparse pebbles, uniform character, in part nearly friable; massive, irregularly fractured	56	1,248
46	Interbedded sandstone and mudstone, with sandstone dominant in uppermost 20 feet, but in about 50:50 ratio below; sandstone, medium grained, faintly laminated, resistant, orange weathering, pebbly layers, medium to thick bedded; mudstone, recessive, contains thin sandstone beds with pebbles and cobbles, ripple laminated in part, macerated carbonaceous debris common	102	1,192
45	Poorly exposed interval, probably thin sandstone and mudstone interbeds as below	13	1,090
44	Interbedded sandstone, thin bedded, and mudstone, approximately 50:50 ratio; sandstone, fine to medium grained, pebbly at bases of beds, laminated, burrowed, rootlets; mudstone, light grey, sandy streaks, rootlets	25	1,077
43	Mudstone with thin coal seams	2	1,052

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
42	Interbedded sandstone and sandy mudstone; sandstone, fine to medium grained, moderately sorted, laminated, ripple-marked, clay drapes on ripple beds, burrows, rare pebble layers, carbonaceous debris common; mudstone-rich beds commonly about 2 feet thick, contain thin beds and laminae of sandstone; mudstone is clayey, soft, grey	32	1,050
	Moved downstream 1/4 mile to equivalent stratigraphic level.		
41	Sandstone, orange weathering, fine grained, in part calcareous, scattered pebbles, fairly uniform, flat shale clasts abundant on bedding soles, rare star-shaped feeding burrows, ripple-marks; minor shaly intercalations and thin interbeds	40	1,018
40	Interbedded sandstone and sandy mudstone, thin bedded, both evenly laminated; sandstone, orange and grey banded, fine to medium grained, minor pebbles and cobbles, abundant carbonaceous fragments, oscillation-ripples common, mudstone contains sandy bands	33	978
39	Sandstone, fine grained, vaguely laminated, some coarse-grained and pebbly bands, partly calcareous; forms large flow rolls, 5 feet high at base of unit	20	945
38	Interbedded sandstone and mudstone, each approximately 2 feet thick; sandstone commonly coarse grained, medium to thick bedded, except thin bedded within mudstone intervals; pebbles and small cobbles common, especially at bases of mudstone beds, shale clasts common	22	925
37	Sandstone, generally fine grained, pebbly and coarse to very coarse grained near tops of beds, minor mudstone interbeds, orange-grey, up to 0.5 foot thick; load casts, burrows and tool-marks on bedding soles; thin to thick bedded, resistant, sharp basal contact	11	903
36	Interbedded sandstone and mudstone, thin bedded, sharp bedding contacts common; sandstone, fine grained, conglomeratic at bases of beds, laminated, mudstone, medium grey, contains 20% lenses of sandstone with reedy carbonized plant fragments abundant	14.5	892
35	Sandstone, fine to coarse grained, banded, shale partings, thin to medium splitting, rootlets, lenticular	2.5	877.5
34	Interbedded grey mudstone, medium- to coarse-grained sand, and minor pebbly sandstone, fine grained, lenticular; recessive	8	875
33	Sandstone, light orange-grey weathering, laminated in part, pebble lenses, shale clast lenses, minor mudstone interbeds, plant rootlets at tops of many beds; medium to thick bedded, sharp basal contact	8	867
32	Underlying interbedded sandstone and mudstone inaccessible, measured only	130±15	859

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
31	Sandstone, light grey, fine grained, uniform; thick bedded to massive, numerous black partings in upper half, friable in part in top 25 feet; sharp basal contact	80	729
30	Mudstone, medium grey, chunky, recessive	2.5	649
29	Sandstone (40%) and sand (60%), very fine to fine grained, laminated, even splitting	8.5	646.5
28	Mudstone, chunky, thin siltstone interbeds, common plant-fragment layers; very recessive	35	638
27	Sandstone (50%) and shale (50%) interbedded; sandstone, medium to coarse grained, bands rich in shale clasts, some small burrows	27	603
26	Conglomerate, pebbly, with rare shale lenses; irregular thickness	1	576
25	Sandstone, pale orange weathering, fine to coarse grained, scattered pebbles, parallel laminations, cross-stratification in nearly planar sets, in part ripple-marked; minor coaly stringers and unconsolidated sand	11	575
24	Mudstone, coaly with minor yellowish sandy layers, medium to coarse grained in uppermost 15 feet; interbedded coaly and ochrous varieties below, the latter silty with plant debris, very soft; very recessive	60	564
23	Coal, black, banded, one blocky-fracturing bed	2	504
	Basal sandstone member (502+ feet)		
22	Sand and sandstone, fine grained, slightly argillaceous, mostly evenly laminated, medium grey, macerated coaly plant debris common, irregular coaly stringers in 3-inch thick bed 20 feet below top; rare mudstone beds, dark grey; scour-and-fill structures, cross-stratification, current lineations	67	502
21	Interbedded sandstone, siltstone and shale; sandstone, very fine to medium grained, in part parallel laminated, commonly burrowed; shale, grey, sandy and pebbly bands and thin beds; siltstone beds in top 15 feet, associated with carbonaceous laminae containing abundant plant fragments. Plant remains identified by C. J. Smiley, Univ. of Idaho, as *Equisetites* sp. (Late Cretaceous)(GSC loc. C-11283)	57	435
20	Sandstone, fine to coarse grained, banded, ripple-marked, clay laminae, planar and festoon cross-stratification, scattered pebbles, thick bedded; basal few feet contain lenses and beds of marlstone	13	378
19	Conglomerate, granular to bouldery, very poorly sorted, lithified, mainly chert clasts, maximum diameter 400 mm	1	365

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
18	Sand and sandstone, light grey, very fine to fine grained, scattered pebbles and cobbles, pyrite nodules; mostly massive, fairly resistant; conglomerate lenses up to 0.5 foot thick in upper half; cross-stratification and scouring common in top 20 feet	83	364
17	Sand, ochrous, fine to medium grained, very limonitic, very recessive, grades into overlying unit	1.5	281
16	Sandstone, orange weathering, fine- and coarse-grained bands, wavy laminations, carbonaceous plant debris, minor shale partings, limonitic crust on top 1-inch layer	0.5	279.5
15	Conglomerate, pebbly to cobbly, slightly limonitic	0.5	279
14	Marlstone, orange weathering, lithographic, light grey, contains minute plant fragments	0.5	278.5
13	Interbedded sandstone, sandy, coal-fragmental mudstone, and conglomerate, cobbly; sandstone, medium grey, in thin uneven beds, with abundant wood fragments, coalified, ripple-marks, parallel laminations; sharp basal contact	3	278
12	Sandstone, fine to coarse grained, crudely laminated, cross-stratified at base, minor friable layers	7.3	275
11	Conglomerate, pebbly, sandy, friable, limonitic in part, grades up into coarse-grained sandstone, coal-fragmental, and capped by shale layer	0.7	267.7
10	Sand, slightly lithified, light grey, medium grained, laminated, poor to fair sorted; recessive	8	267
9	Coal, black, partly laminated, shaly in part, very recessive	4	259
8	Sandstone, fine- and medium-grained bands, sparse chert pebbles and pyrite nodules, low-angle cross-stratification; mainly massive, resistant	19	255
7	Sandstone, fine to coarse grained, pebble layers, slightly calcareous, quartz-chert-lithic arenite, parallel laminated, cross-stratified in part, in part covered or poorly exposed	47	236
6	Interbedded sandstone and mixed mudstone-sandstone beds, 1 to 2 feet thick; recessive, poorly exposed; sandstone beds thick, slabby fracturing	22	189
5	Sandstone, basal parts of beds coarse grained and pebbly, upper parts fine grained, parallel laminated, poorly consolidated, medium to thick bedded; mudstone interbeds in basal 10 feet; bedding soles show burrows, scratch marks, and groove-casts	25	167
4	Mudstone, medium grey, chunky fracturing, with minor thin-bedded sandstone, fine grained, laminated, burrowed, in part lenticular; scoured, sharp basal contact	14	142

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
3	Sandstone, light grey, fine grained, moderately sorted, slightly calcareous, in part porous; parallel laminated and planar cross-stratified, shale clast bands common, burrowed shaly laminae near top; medium to thick bedded	13	128
2	Covered by stream alluvium of valley floor	100	115
1	Interbedded conglomerate, sandstone, and mudstone in 1- to 2-foot thick beds; conglomerate is channelled, with clay drapes, and overlain by sandstone or conglomerate beds; sandstone and mudstone occur as thin interbeds in 3-foot sub-units; some sandstone shows planar cross-stratification	15	15

Section 9: Section of Reindeer and Moose Channel Formations and part of Tent Island Formation poorly exposed in axial part of Deep Creek Syncline on Yukon Coastal Plain in vicinity of Lat. 68°51'N, Long. 137°58'W. Stratigraphic units and their thicknesses are based largely on three ground traverses and airphoto interpretations. High-level (A14406-58, -59) and recently flown, low-level, high-resolution, vertical aerial photographs were used and integrated with lithologic and structural control obtained on the ground.

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	LOWER TERTIARY OR UPPER CRETACEOUS		
	Reindeer Formation (785±150 feet)		
	Highest beds in centre of syncline; top not exposed.		
19	Covered, recessive interval, probably mudstone of uncertain thickness	170±20	3,035
18	Sandstone, light rusty grey, fine grained, compact, in part poorly sorted, platy fracturing, 10% chert; minor red sandstone, fine grained, micaceous, thin bedded	170±15	2,865
17	Mudstone, uniform, dark airphoto unit	45	2,695
16	Sandstone, light grey, fine grained with coarse sand and granules present, moderately to poorly sorted, quartzose, 15% chert and dark fragments, platy and thin bedded, porous in part	115	2,650
15	Mudstone, uniform, dark airphoto unit	85	2,535
14	Sandstone, very fine to fine grained, chert granules common, rusty specks very abundant, compact, subangular to subrounded grains; very thin bedded	200±10	2,450

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	UPPER CRETACEOUS		
	Moose Channel Formation (2,250 feet)		
13	Mudstone, uniform in upper 50 feet; interbedded with sandstone below with pebble horizons; possibly contains coal beds; sandstone, rusty grey, very fine to very coarse grained beds, moderate to poor sorting, in part porous, rare low-angle crossbedding; pebbly beds fill scour-structures in part, contain phenoclasts up to 90 mm in diameter, composed of black chert and white quartzite. Sharp basal and upper contacts	380±35	2,250
12	Covered; recessive interval, traceable throughout area; probably underlain by mudstone; thickness seems much greater in north than south	250±25	1,870
11	Conglomerate and sandstone, forming a lenticular, resistant unit, possibly not at same stratigraphic level everywhere in outcrop area; conglomerate consists mainly of chert pebbles and coarse sand, minor shale rip-up clasts; sandstone is fine to coarse grained, argillaceous, poorly sorted, with some large-scale cross-stratification	70±10	1,620
10	Covered, recessive interval everywhere, probably mudstone	300±10	1,550
9	Sandstone, light to medium grey, fine to medium grained; poor to moderate sorting, in part argillaceous, in part chert-pebbly; in part hard and non-porous, in part porous; irregular to even bedded; current lineations, carbonaceous debris, coaly fragments, bedding-plane trails, ripple laminae; quartz-lithic-chert grain components	360±20	1,250
8	Covered, recessive unit, probably mudstone	140	890
7	Sandstone, light grey, mainly fine grained, thin bedded; quartz with 25% chert, minor potash feldspar, thin, irregular bedding; 1- to 2-foot thick graded sets at base, changing laterally into pebble conglomerate with sand lentils	100	750
6	Covered, recessive unit, no exposures	100±10	650
5	Very poorly exposed unit interpreted as interbedded sandstone and mudstone from aerial photographs	85	550
4	Covered, recessive unit, probably mudstone	50	465
3	Sandstone, light grey, fine grained, moderately sorted, trace porosity; probably thinly bedded	95	415
2	Covered, recessive unit, probably mudstone	90	320
1	Sandstone, mainly fine grained, coarse-grained beds common, quartz-chert-feldspar composition, pebbly layers minor, moderately sorted; resistant at top and bottom but not in middle portion, possibly due to shaly interbeds	230	230

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	Tent Island Formation (upper part only; 610 feet)		
4	Covered, recessive unit, appears uniform	110±10	610
3	Mudstone, not exposed, with minor sandstone beds, fine grained, poorly to moderately sorted, 25% chert, rare coarse-grained sand and pebbly beds, in part porous	250±25	500
2	Mudstone, brown-black, carbonaceous to coaly, silty, chunky; rare sandstone, dark grey, fine grained, poorly sorted, carbonaceous debris, micaceous, homogeneous fabric	150	250
1	Not exposed, recessive, probably mudstone for considerable thickness below	100+	100