GEOLOGICAL SURVEY OF CANADA
COMMISSION GÉOLOGIQUE DU CANADA

PAPER 79-32

GEOLOGY AND COAL RESOURCE POTENTIAL OF EARLY TERTIARY STRATA ALONG TINTINA TRENCH, YUKON TERRITORY

J. D. Hughes
D. G. F. Long

Energy, Mines and
Resources Canada

Énergie, Mines et
Ressources Canada

1980

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Available in Canada through

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Canadian Government Publishing Centre
Supply and Services Canada
Hull, Québec, Canada K1A 0S9

and from

Geological Survey of Canada
601 Booth Street
Ottawa, Canada K1A 0E8

A deposit copy of this publication is also available for reference in public libraries across Canada

Cat. No. M44-79/32E	Canada:	$3.50
ISBN 0-660-10597-7	Other countries:	$4.20

Price subject to change without notice

Critical readers

J.A. Irvine
J.R. McLean

Authors' address

Institute of Sedimentary and
Petroleum Geology
3303 33rd Street N.W.
Calgary, Alberta T2L 2A7

Original manuscript submitted: 79/8/9

Manuscript approved: 80/4/3

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GEOLOGY AND COAL RESOURCE POTENTIAL OF EARLY TERTIARY STRATA ALONG TINTINA TRENCH, YUKON TERRITORY

Abstract

Early Tertiary (Paleocene-Eocene) coal-bearing strata, including sandstones, conglomerates and mudstone of alluvial and lacustrine origin, occur within Tintina Trench in southern and central Yukon Territory. Tintina Trench is a major linear structural feature along which late Cretaceous right-lateral movement in the order of 450 km has been postulated. At least some post-Eocene movement is indicated, however, as these strata are moderately to strongly deformed at most localities.

The early Tertiary succession is generally very poorly exposed, as large parts of the Trench are mantled by thick glacial and alluvial deposits and the coal-bearing strata are generally poorly consolidated. Its total thickness is probably highly variable and Tertiary strata may be absent at some locations. Minimum thicknesses of 700 to 800 m are indicated near the town of Ross River and northwest of Dawson.

Coal seams ranging in rank from lignite to semi-anthracite occur along the Trench near Watson Lake, Ross River and between Dawson and the U.S. border. Thin seams also occur within undated strata of possibly equivalent age near the Trench in the Dawson and Watson Lake areas. The anomalously high rank of the bituminous to semi-anthracite coals near Ross River and of the anthracite coal south of the Trench near Dawson, probably relates to thermal upgrading by nearby intrusions.

Coal resource potential is limited by the structural complexity, lateral variability and restricted extent of coal-bearing strata within the Trench. Limited exposure prevents useful resource estimates; however, small, potentially mineable deposits are indicated near Dawson and Ross River. The structural complexity and generally low rank of the coals suggests that exploitation by current underground mining methods would be impractical. Surface mining would have to be restricted to small-scale operations and, in the Watson Lake area, economics may be adversely affected by the thick surficial deposits covering the bedrock.

Résumé

Dans le sillon de Tintina, au sud et au centre du Yukon, on trouve des couches de charbon datant du début du Tertiaire (Paléocène-Éocène), contenant des grès, des conglomérats et des pélites d'origine alluviale et lacustre. Le sillon de Tintina est une importante structure linéaire suivant laquelle, on pense qu'un mouvement latéral dextre de l'ordre de 450 km ait pris place à la fin du Crétacé. On peut, au moins, constater certains mouvements post-éocènes, car ces couches sont, à plusieurs endroits, modérément à fortement déformées.

Les roches du début du Tertiaire n'affleurent qu'en de rares endroits puisque de grandes sections du sillon sont recouvertes d'épais dépôts glaciaires et alluviaux, tandis que de manière générale les couches de charbon ne sont pas bien consolidées. L'épaisseur totale des roches tertiaires est probablement très variable et celles-ci sont absentes à certains endroits. On trouve des épaisseurs minimales de 700 à 800 m près de Ross River et au nord-ouest de Dawson.

On trouve des couches de charbon dont le rang varie de la lignite à la semi-anthracite, le long du sillon près de Watson Lake, de Ross River et entre Dawson et la frontière des É.-U. On trouve aussi des couches minces au sein des strates non datées, mais d'un âge probablement équivalent, près du sillon dans les régions de Dawson et de Watson Lake. Le rang anormalement élevé des charbons gras et semi-anthracites situés près de Ross River, et des charbons anthracites situés au sud du sillon, près de Dawson, sont probablement liés à l'évolution thermique des intrusions avoisinantes.

Le potentiel houiller est limité par la complexité de la structure, la variabilité latérale et l'étendue restreinte des couches de charbon au sein du sillon. L'affleurement réduit des couches empêche de faire des estimations utiles des ressources; cependant, il existe, près de Dawson et de Ross River, des gisements exploitables. Étant donné la complexité de la structure et le rang généralement faible des charbons, il n'est pratiquement pas possible d'en faire l'exploitation en utilisant les techniques minières souterraines actuelles. L'exploitation en surface devrait donc être limitée à des opérations à petite échelle et, dans la région de Watson Lake, le rendement sera probablement faible à cause d'épais dépôts de surface recouvrant la roche en place.

GEOLOGY AND COAL RESOURCE POTENTIAL OF EARLY TERTIARY STRATA ALONG TINTINA TRENCH, YUKON TERRITORY

INTRODUCTION

Coal-bearing strata of early Tertiary age have been known to occur along Tintina Trench in southern and central Yukon since the gold rush era of the late nineteenth century and have been mapped during regional studies by the Geological Survey over the last three decades. Three small coal mines, one of which supplied a thermal-electric generating plant, worked seams along the Dawson segment of the Trench in the early part of this century. Later attempts to exploit this coal have been hindered by its low rank (typically lignite), structural complexity and distance from prospective markets.

Interest in these coals has been renewed by a recent proposal for a natural gas pipeline from the Prudhoe Bay and Mackenzie Delta fields. This pipeline may follow parts of Tintina Trench and could utilize small, coal-fired thermal-electric plants as a source of local power for pumping stations. This study was undertaken to provide an understanding of the stratigraphic and structural framework of the coal-bearing early Tertiary rocks in order to assess their potential as an energy resource.

This report is based on field work undertaken in the summer of 1978, during which time all known exposures of early Tertiary sedimentary rocks along the Yukon portion of Tintina Trench were visited. Exposures of coal-bearing strata near Indian River, south of the Trench in the Dawson area and near Watson Lake, on trend with the southeastern limit of the Trench, were also examined.

This report is intended to present structural, stratigraphic and coal quality data relevant to resource evaluation of these strata. A subsequent report (Long and Hughes, in prep.) will deal with the sedimentology of the sequence.

Acknowledgments

The maceral composition of the Tintina Trench coals (Table 1) was provided by A.R. Cameron and S. Creaney, and the vitrinite reflectance (Tables 2, 3 and 4) by S. Creaney and L. Marconi. Proximate analyses, sulphur content and calorific values (Tables 2, 3 and 4) were provided under contract. Able assistance in the field and office was rendered by I.C. Fahrner and K. Kingsmith. Officers of Placer Development Ltd. kindly provided samples for palynological work and discussed their exploration program in the Watson Lake area. J.A. Irvine, B.A. Latour, J.R. McLean and D.K. Norris read the manuscript and suggested improvements.

Previous work

Early reports on coal-bearing strata along Tintina Trench are restricted to the Dawson area, where coal was noted during extensive prospecting for gold at the turn of the century. McConnell (1903) reported coal-bearing sedimentary rocks exposed along streams crossing the Trench for 100 km between Klondike River and Cliff Creek (Fig. 1) and estimated these strata to underlie an area in excess of 500 km^2. Coal mines on Cliff and Coal Creeks and the Gates Mine near Dawson were described, while in production, by McConnell (1903, 1906) and Collier (1903). Later references to these mines and to the Tertiary succession of the Dawson area in general were made by Bostock (1938, 1942), Green and Roddick (1962), Green (1972, 1977), Milner and Craig (1973), Hopkins et al. (1975) and Milner (1978).

Lithologically similar coal-bearing rocks located south of the Trench in the Dawson area were described by McConnell (1906), Bostock (1942), Tempelman-Kluit (1974) and Milner (1978). Coal-bearing rocks within and south of the Trench in Alaska were described by Collier (1903), Prindle (1913), Mertie (1930, 1937), Hollick (1936), Brabb and Churkin (1964a, b) and Clark and Foster (1968).

Southeast of Dawson, Tertiary strata have been mapped in the Trench at Clear Creek by Bostock (1964) and along Pelly River by Roddick and Green (1961) and Tempelman-Kluit (1972). Coal-bearing strata in the Trench near Ross River were noted by Kindle (1946), Wheeler, Green and Roddick (1960), Milner and Craig (1973) and Tempelman-Kluit (1977b). MacKay (1947) and Gabrielse (1963a, b; 1967) recorded coal-bearing strata underlying Liard Plain near Watson Lake.

TINTINA TRENCH

Tintina Trench is one of several subparallel lineaments in the south-central Yukon and Alaska along which major right-lateral strike-slip displacement is inferred (St. Amand, 1957; Grantz, 1967). It is a major linear topographic feature that extends 960 km from Liard Plain, in southeast Yukon, to Woodchopper Creek, in east-central Alaska. The Trench is on trend with the northern end of Rocky Mountain Trench on the southeast and merges with the Kaltag Fault in Alaska (Grantz, 1967) (Fig. 1). The floor of the Trench ranges from 2 to 12 km in width and is occupied by parts of Yukon, Stewart, MacMillan, Pelly, Hoole, Black and Liard Rivers. Relief between floor and walls generally ranges from 300 to 600 m, however in places one or both walls are of low relief and the Trench is poorly defined. Relief on the floor is generally low, except along the unglaciated part northwest of Dawson (Vernon and Hughes, 1966), where the Trench is dissected by several transverse southwest-flowing streams.

Estimates of the magnitude of right-lateral displacement on the Canadian portion of Tintina Trench, based on tentative correlations of late Proterozoic to early Cretaceous rock units across the Trench, range from 400 to 450 km (Roddick, 1967; Tempelman-Kluit, 1970, 1977a, 1979), whereas estimates on the American portion range from 80 to 250 km (Grantz, 1967, p. 35). Most of this movement occurred in late Cretaceous or younger time, as lower Cretaceous sedimentary rocks and possibly mid-Cretaceous plutonic and volcanic rocks have been displaced (Roddick, op. cit.; Tempelman-Kluit, 1970). At least some post-Eocene movement is indicated, as coal-bearing Paleocene-Eocene strata in the Trench are at some localities highly deformed. Milner (1978) cited several lines of evidence for 50 km of post-Eocene movement, based mainly on apparently offset physiographic features presumably developed in the mid- or late Tertiary. Aho (1959) suggested the most recent movement occurred during the late Tertiary and involved dip-slip components which, on physiographic evidence, were at least 750 m at some localities.

Movement along the Trench probably involved several subparallel interconnected faults rather than a single fault plane. Several steeply dipping to vertical faults, some with dip-slip components of at least 1500 m, have been mapped within a 10 km wide part of the Trench near Faro by Tempelman-Kluit (1972). Stratigraphic relationships indicate these faults moved in early Triassic and late Cretaceous time and, although there is no direct evidence of strike-slip on these faults, Tempelman-Kluit (op. cit.) suggested the length and continuity of the fault system, the ambiguous dip-slip relations across some of these faults and the presence of

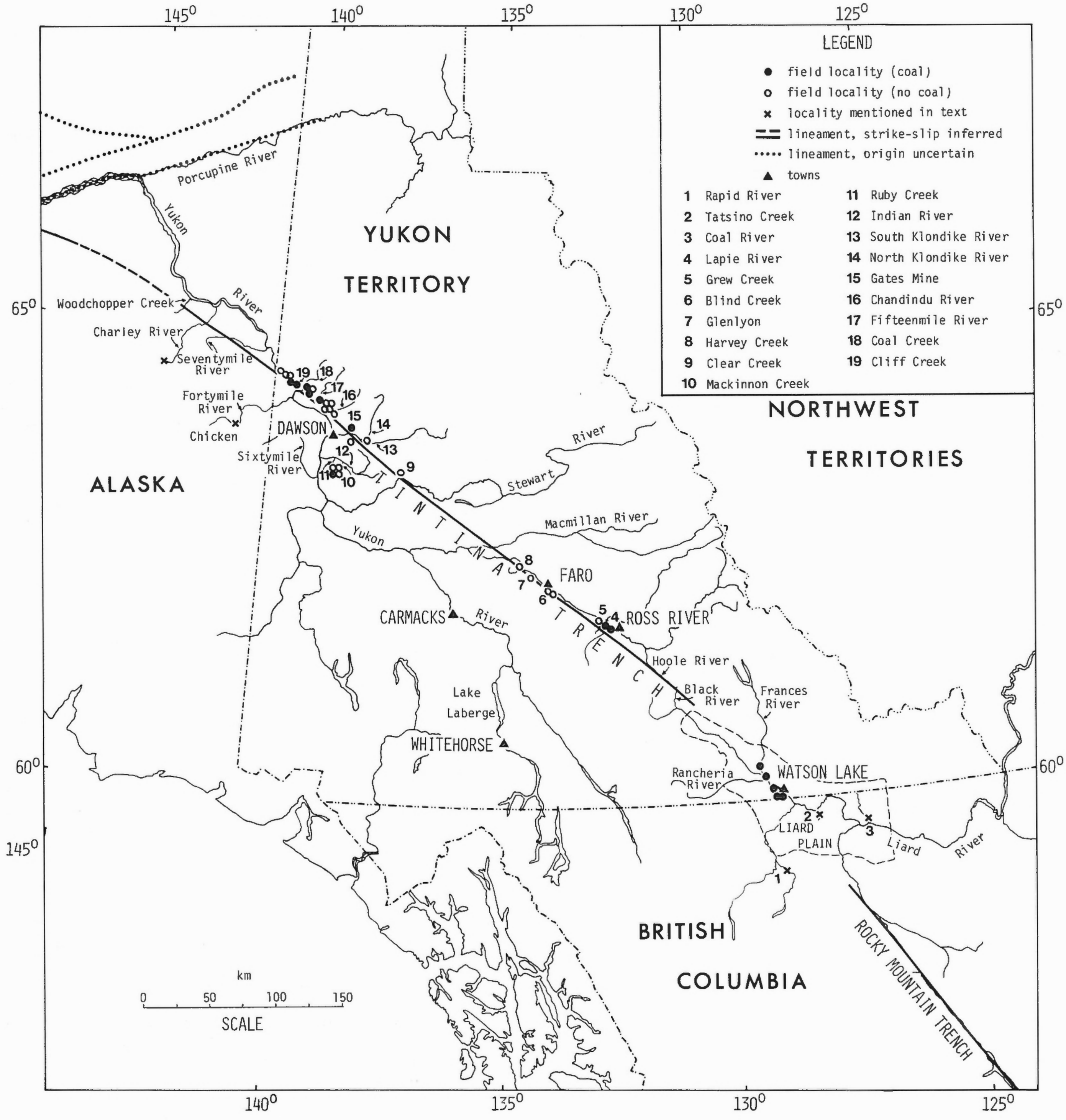


FIGURE 1. *Tintina Trench and the location of features mentioned in text.*

untilted blocks between faults indicate major strike-slip movement. Southeast of Dawson, wide fault gouge zones within the Trench have been intersected in boreholes and are exposed in open-cut placer mines and in road cuts along Klondike River (Aho, 1959).

In summary, a large part of approximately 450 km of right-lateral strike-slip displacement along Tintina Trench probably occurred during the late Cretaceous. This displacement, along with associated or subsequent dip-slip movement, created a series of fault-bounded elongate basins within which clastic detritus and coal were deposited during early Tertiary time. Subsequent dip- and/or strike-slip movement deformed these sediments and resulted in the present physiographic expression of the Trench.

DISTRIBUTION OF TERTIARY STRATA

Coal occurrences within Tintina Trench and adjacent basins are associated with thick sequences of sandstone, siltstone, claystone and conglomerate. Exposures are rare, as these rocks are, in most cases, poorly indurated and large segments of the Trench are covered with thick surficial deposits of glacial, lacustrine and alluvial origin.

In Watson Lake map-area, exposures of early Tertiary strata are confined mainly to cutbanks along Liard and Frances Rivers, although these strata may be present over a much larger area beneath surficial deposits covering Liard Plain (Fig. 1). Coal-bearing strata are exposed in adjacent McDame map-area along Tatsino Creek, about 50 km southeast of Watson Lake (Klassen, pers. com., 1978), and along Rapid River, 100 km south of Watson Lake (Gabrielse, 1963a). In Rabbit River map-area coal-bearing strata are exposed along Coal River, about 75 km east-southeast of Watson Lake (Gabrielse, 1963b). Both the Rapid River and Coal River occurrences appear to have a limited lateral extent and were not visited during the course of this study.

Between Watson Lake and Ross River the Trench is narrow and reaches its maximum elevation. No coal-bearing strata have been reported along this segment.

Near Ross River, coal-bearing sequences are well exposed on Lapie River and along Canol Road, 3 km southwest of the townsite, where they occur within tilted but relatively undeformed blocks bounded by steeply dipping faults. Twenty-five kilometres northwest of Ross River, highly contorted siltstone, shale and conglomerate are exposed along Grew Creek. Along Pelly River, 20 km northwest of Grew Creek, deformed sandstone, siltstone and minor conglomerate (at one locality cut by a basic dike) are sporadically exposed for 3 km. Surficial cover adjacent to these exposures is of substantial but variable thickness. Near the Pelly River occurrences, surficial deposits are in the order of 30 to 50 m thick.

Undated, non coal-bearing sequences of pebble to boulder conglomerates outcrop on the southern margin of the Trench near Glenlyon Lake (Fig. 1), where they are mapped as Paleocene (Roddick and Green, 1961), and within the Trench, near Harvey Creek, where they are mapped as Upper Jurassic(?) and Lower Cretaceous(?) or early Tertiary (Campbell, 1967) (Fig. 1). These conglomerates are generally much coarser and less mature than Tertiary conglomerates observed elsewhere in the Trench and contain few sand-sized or finer beds and no plant remains. They have tentatively been correlated with the Tertiary succession because of their proximity to the Trench; however, their dissimilar lithologic and sedimentologic attributes suggest they may be of a different age. Clasts within the Harvey Creek conglomerates are predominantly sedimentary and low rank metamorphic varieties. They include angular to subrounded pebbles, cobbles and rare boulders of grey to white quartzite, grey and buff limestone and dolomite, and minor quartz, argillite, slate and chert. A probable source is the adjacent Lower Paleozoic Askin Group (Campbell, 1967), which is part of the autochthonous suite of Tempelman-Kluit (1979). This suggests these conglomerates predate emplacement of Tempelman-Kluit's (op. cit.) allochthonous assemblage in the Late Jurassic to Early Cretaceous and therefore are of Early Cretaceous or older age. Clasts in the conglomerates of the Glenlyon area include, in addition to the lithologies mentioned above, up to 15 per cent granite in some beds. If these granitic clasts were derived from the adjacent batholith of Glenlyon Range, the conglomerates are Late Cretaceous or younger. Alternatively, the clasts may be derived from older granites known in this vicinity (Campbell, 1967) and the conglomerates could thus be equivalent to those at Harvey Creek. As coal is not found in association with these conglomerates, no further consideration is given to them in this report.

A small exposure of poorly consolidated pebbly sandstone, conglomerate and minor siltstone along Clear Creek is the only reported occurrence of probable early Tertiary strata along the 230 km segment between Harvey Creek and South Klondike River (Bostock, 1964). The remainder of this segment is covered by surficial deposits which, in the area northwest of Stewart Crossing, may be up to several hundred metres thick (Bostock, 1966).

Between South Klondike and Chandindu Rivers slumped Tertiary deposits are covered by extensive glacial outwash and colluvium (Vernon and Hughes, 1966; Green, 1972). Exposures include a deformed sequence of siltstone, sandstone, conglomerate and thin coal seams which outcrops along a drainage ditch between North and South Klondike Rivers and a small exposure including a thin coal seam at Gates Mine on Coal Creek (Fig. 1).

Between Chandindu River and the Alaska border surficial cover is relatively thin away from the floodplain of Yukon River. The Trench is between 2 and 5 km wide along this segment and sparse exposures of early Tertiary rocks occur within slump scarps, along ridge crests and in stream valleys. This segment has not been affected by glaciation and comprises the largest area in the Canadian part of the Trench that is known to be underlain by Tertiary strata at shallow depth.

In Alaska, the Tertiary outcrop belt widens to between 3 and 22 km and extends along the Trench for 135 km to Woodchopper Creek (Prindle, 1913; Mertie, 1930, 1937; Clark and Foster, 1968). Several coal occurrences have been reported along this segment and Tertiary strata are in general more completely exposed than in the Canadian part.

Scattered occurrences of coal-bearing rocks of probable early Tertiary age occur south of the Trench along Indian River and its tributaries Ruby and McKinnon Creeks, and further west along Yukon and Sixtymile Rivers (Bostock, 1942; Tempelman-Kluit, 1974) (Fig. 1). In Alaska, coal-bearing, possibly equivalent, rocks occur south of the Trench at Chicken and along Charley Rivers (Fig. 1). These strata are lithologically similar to those in the Trench and may have accumulated within small basins at about the same time, although they remain undated at present.

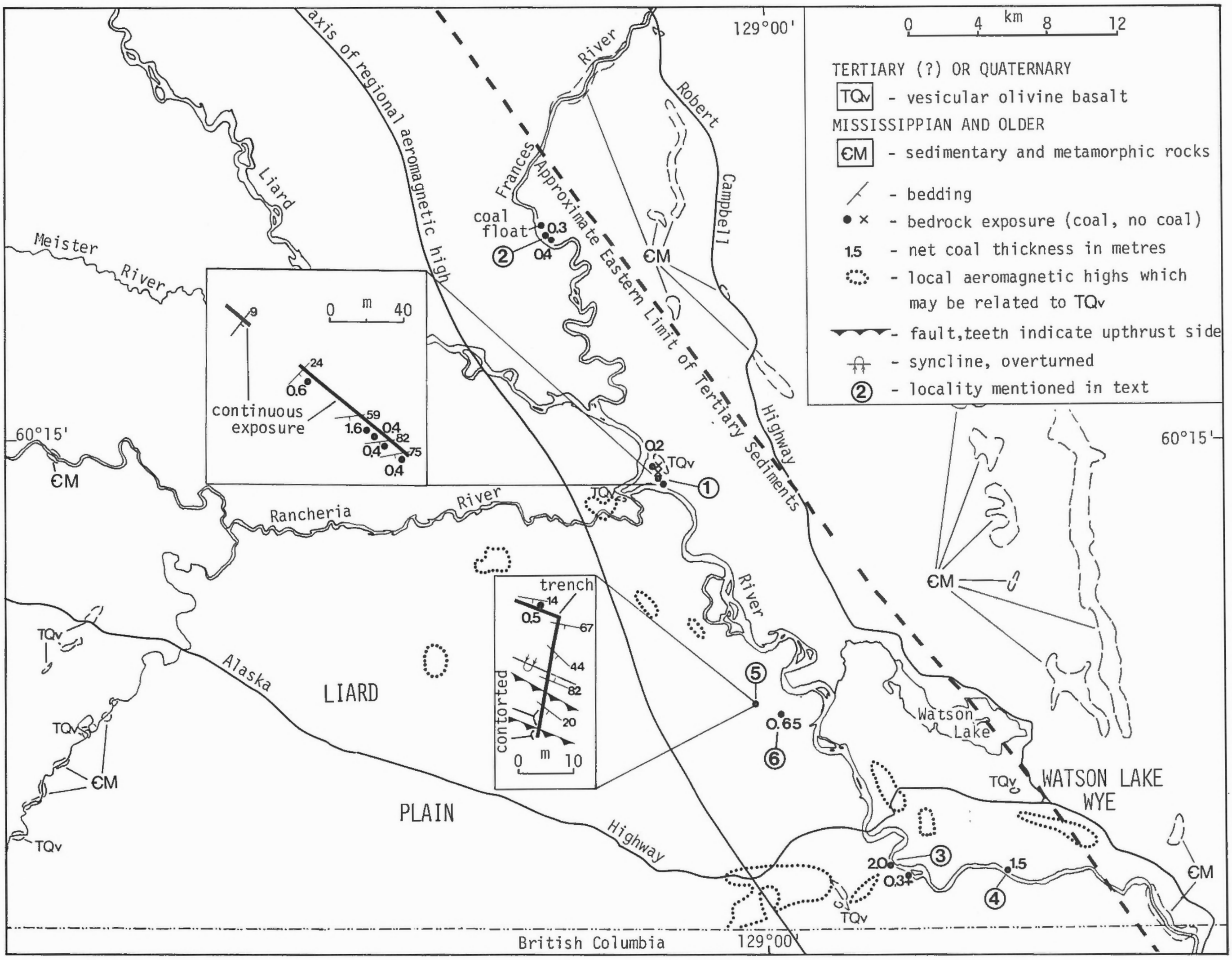


FIGURE 2. Generalized geology of Watson Lake area showing field localities, net coal thickness and aeromagnetic anomalies (modified from Gabrielse, 1967).

GEOLOGY OF COAL AREAS

Although Tertiary sediments may be present beneath surficial cover along a substantial portion of the Trench, areas of present exposure and potential coal resources are restricted mainly to the Watson Lake, Ross River and Dawson segments. The geological setting of these areas and of the Indian River occurrence south of the Trench near Dawson are discussed in the following section.

Watson Lake area

Watson Lake lies near the centre of Liard Plain, a southeast trending intermontane basin of low relief some 175 m long and 50 km wide. Glacial and lacustrine deposits up to 60 m in thickness cover most of the area (Klassen, 1978a). Alluvial deposits adjacent to major rivers are up to 100 m in thickness (Klassen, op. cit.). Exposures of underlying bedrock are limited to cutbanks along Liard and Frances Rivers and to exploration trenches west of Liard River (Fig. 2). Some bedrock exposures are highly deformed, both by tectonic and glacial processes, and those along river cutbanks are commonly slumped.

Coal-bearing strata

The thickest exposure of coal-bearing rocks in the area occurs on the east side of Liard River 2 km below its junction with Rancheria River (Loc. 1, Fig. 2). Eighty metres of moderately to steeply dipping, poorly indurated claystone, siltstone, sandstone and minor pebble conglomerate are exposed at this locality. Dip steepens southward within this section from 9 to 82°. These rocks are sharply truncated and overlain by horizontally stratified gravels of possible fluvioglacial origin (Fig. 3).

Five coal seams between 0.4 and 2.1 m in thickness and several thinner coaly beds are present at Locality 1. The coal is of lignite A and B rank and, where weathered, annular rings of individual logs are easily separable. Resin nodules up to 1 cm maximum dimension occur singly and in lenticular layers up to 2 cm thick within some seams. Parts of the thickest seam have an ash content of up to 50 per cent. Light grey to brown weathering claystones and siltstones comprise over half of the section. Rooted zones, abundant plant remains and coaly streaks are present within these beds at some levels whereas other beds appear massive. Tree trunks in growth positions are present within a silty-claystone bed near the top of the section. Sandstones weather brown to grey and are fine- to coarse-grained. Coarser varieties are characterized by trough and planar cross-stratification, finer varieties by ripple cross-laminations. Conglomerates, a minor component of this section, are of small pebble grade, and are characterized by both crude lamination and, in parts, planar cross-stratification. Crude fining upward sequences are evident within some of the sandstone and conglomerate beds, and two sequences grading upward from pebble conglomerate to claystone and coal are present near the base of the section.

North of Locality 1, two bedrock exposures and coal float occur along the east side of Frances River 10 km above its junction with Liard River (Loc. 2, Fig. 2). Very little bedrock is exposed here, and the outcrops may be within slump blocks. Observed dips are less than 10°. At the northern outcrop shown on Figure 2 near Locality 2, 34 cm of woody coal overlies 1 m of dark grey to black carbonaceous shale and grey claystone with abundant plant remains. At the southern outcrop, a 30 cm thick bed of coal is overlain by 2 m of dark grey to black, soft carbonaceous clay and coaly shale.

At Locality 3 (Fig. 2), on the west bank of Liard River 2 km south of the Alaska Highway bridge, a 2 m thick coal seam is exposed. Ice movement and possibly tectonism have deformed this exposure and the coal seam may be structurally thickened. Claystone underlying this seam is deformed. One kilometre southeast, a steeply dipping seam at least 30 cm thick (base not exposed) outcrops in a road cut. At Locality 4, 6 km further east on the north bank of Liard River (Fig. 2), a 1.5 m thick seam underlain by dark grey claystone was exposed by trenching. The observed dip is north at 35°, however this exposure may have been rotated by slumping.

FIGURE 3. Steeply dipping early Tertiary strata including 2.1 m thick coal seam overlain by flat-lying gravels at Locality 1 (Fig. 2).

An exposure within an exploration trench at Locality 5 (Inset, Fig. 2) illustrates the high degree of deformation some of the coal-bearing strata have undergone. A sequence comprising 24 m of partly covered grey to white weathering claystone, siltstone, thin coal seams and minor sandstone overlain by 8 m or more of medium grained pebbly sandstone, has been intensely folded and faulted. Numerous steeply south dipping reverse faults, with displacements ranging from a few centimetres to several metres, and northward overturned folds are evident (Fig. 4). The magnitude and intensity of these structures suggest they are preglacial features. About 2 km southeast, at Locality 6 (Fig. 2), 3 m of soft, dark to light grey weathering claystone including one 45 and two 10 cm thick coal seams, is exposed in a second exploration trench. These beds dip east at 20°. Overlying strata are complexly deformed, possibly by ice movement.

Placer Development Ltd. has drilled several continuous core holes to depths of up to 150 m and opened the trenches west of Liard River. Aggregate coal intersections of up to 15 m are reported by the company in some of these holes. Dips reported in the core are less than 25°. The lack of evidence in the core for deformation comparable to that observed at Localities 1 and 5 (Fig. 2) may be in part related to the poorly consolidated nature of the strata, which often results in poor recovery of coarser lithologies and difficulty in distinguishing bedding. Tentative correlations made by the company between several holes spaced 1 to 1.5 km apart and located south of the Alaska Highway near Locality 3, suggest subsurface deformation in this area at least is relatively minor.

Preliminary palynological work on two suites of samples from coal-bearing sediments in three of the core holes indicates "...upper Paleocene or possibly lower Eocene..." and Eocene, "...probably Upper Eocene...", ages (Hopkins, 1978a, 1978b). Work is currently in progress on samples collected during the 1978 field season which should expand the recorded microflora and provide a more specific age determination.

Volcanic rocks

Flat-lying olivine basalt flows, which could affect the economics of mining the otherwise poorly consolidated coal-bearing strata, are present at several localities within Liard Plain (Gabrielse, 1963a, 1967). Gabrielse (1967) has mapped flows near Watson Lake Wye (Fig. 2), at the junction of Liard and Rancheria Rivers, and southwest of the Alaska Highway bridge on Liard River. Other occurrences were noted during the course of this study 1 km north of Locality 1 and near Locality 3 (Fig. 2). Maximum thickness of these flows ranges from 4 to 10 m, and their distribution appears to be reflected by local aeromagnetic highs. The limited size of these aeromagnetic anomalies suggests each flow has a relatively small areal extent. The probable distribution of lava from outcrop and aeromagnetic data is shown on Figure 2.

Although dates are not yet available for these rocks, they post-date the deformation that has affected the Eocene sediments and therefore are probably of late Tertiary or Pleistocene age. Klassen (1978b, p. 1886) suggests they are equivalent to "...the oldest Quaternary deposits..." and that they may "...span the transition from late Tertiary to Quaternary...".

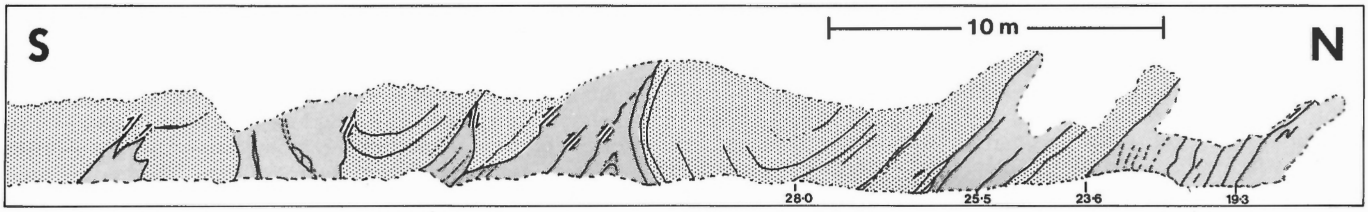


FIGURE 4. Field sketch of part of section exposed within Trench at Locality 5 (Fig. 2). Sandstones indicated by coarse stipple, mudrocks by fine stipple. Number below section indicates height in metres above stratigraphic base of exposure.

Inferences on basin geometry

The areal distribution and thickness of Eocene strata beneath Liard Plain is uncertain, and can ultimately be determined only by further trenching, drilling and geophysical work. The area forms the junction between Tintina and Rocky Mountain Trenches and, although there is no connecting physiographic lineament, the deformation of some of the coal-bearing strata may be related to movement on these features. The trends of these Trenches differ by 10° and if strike-slip movement along them was contemporaneous, Liard Plain formed an area of bending in the fault system, hence deformation could have encompassed a broader area than along the straight segments of each trench. Subsidence created by normal and reverse components of movement on faults within this area of bending may have provided more favourable sites for accumulation and preservation of thick sedimentary sequences than more stable off-trench locations, as at Rapid River and Tatsino Creek in the McDame map-area to the south.

An approximate eastern limit of coal-bearing strata defined by the linear arrangement of exposures of older rocks is shown on Figure 2. Sediments east of this line, if present, are probably of local extent, as in off-trench basins to the south. A western limit is difficult to define but is constrained by the occurrence of older rocks 24 to 30 km west of Liard River. A regional aeromagnetic high, roughly parallel to the trend of Tintina Trench and 5 to 10 km west of Liard River (Fig. 2), may be related to faults near the axis of the basin.

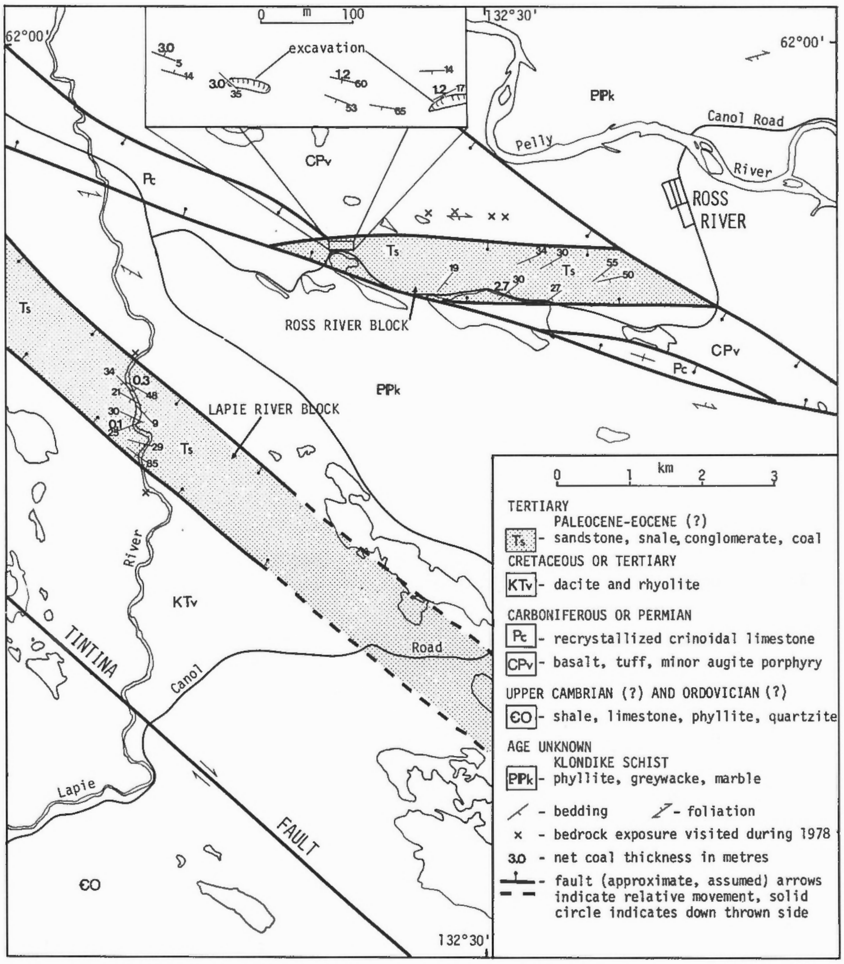


FIGURE 5. Generalized geology of Ross River ara showing net coal thickeness (modified from Tempelman-Kluit, 1977b, pers. com., 1979).

Ross River area

In the Ross River area coal-bearing rocks are exposed along Lapie River and near Ross River townsite. They occur within two fault-bounded blocks referred to as the Lapie River and Ross River blocks. The inferred distribution of these rocks and structural relations within the area are shown in Figure 5. The geometry of these fault blocks is uncertain, owing to extensive surficial cover, hence other areas underlain by early Tertiary strata may be present in this vicinity.

Lapie River block

Early Tertiary strata along Lapie River abut older metamorphic and igneous rocks to the northeast and southwest along two major northwest-trending faults (Fig. 5). Vertical separation on these faults is in the order of several hundred metres. Strike-slip cannot be demonstrated as the fault zones are poorly exposed; horizontal slickensides on small parallel fractures near the southwest fault, however, suggest strike-slip could have been a significant or even dominant component of movement. The position of these faults away from Lapie River as shown on Figure 5 is conjectural owing to extensive surficial cover.

Over 400 m of well-indurated conglomerate, sandstone, siltstone and shale along with minor coal are partially exposed along Lapie River between the faults. The strata generally dip southwest at from 25 to 35°, but are gently folded midway between the bounding faults and dip steeply near the fault zones. The lowermost 120 m of section is dominated by laminated claystone and siltstone and contains two thin lenticular coal seams with maximum thicknesses of 30 cm. Minor sandstone and conglomerate beds are present in the middle part of this unit within both coarsening and fining upwards sequences. Conglomerates associated with the latter are distinctly lenticular, and occur within channels up to 12 m wide (Fig. 6) characterized by rapid lateral facies changes. Above this is a 35 m thick unit of massive to weakly stratified, medium to small pebble conglomerates with minor flat bedded and planar cross-stratified sandstones; a poorly exposed 175 m thick unit of sandstone, siltstone and claystone with minor conglomerate beds near the base and top and a thin (0.1 m) coal seam in the upper part; and an upper unit, at least 100 m thick, in which massive to stratified medium to small pebble conglomerates are exposed between extensive covered intervals.

Conglomerates within the Lapie River section occur in bed sets up to 15 m thick which commonly have well-defined lower contacts. Clasts are subangular to rounded with maximum size between 1 and 7 cm. They consist mainly of resistant lithologies, including tectonized chert and cherty siltstone, grey and white quartzites, vein quartz and lesser amounts of other metamorphic rock fragments, set in a matrix of medium to coarse-grained sandstone. Plane bedded and cross-stratified, medium to very coarse sandstone occurs, in association with small pebble and granule conglomerate, infilling small channels (Fig. 6) within the finer grained parts of the section, and as more laterally extensive beds in association with the coarser conglomerates. Sandstones within coarsening upwards sequences in the lowermost unit are flat laminated and in part ripple cross-laminated. The horizontally laminated claystones and siltstones are commonly micaceous and fissile and in places contain well preserved plant remains. Mudrocks in close association with sandstone and conglomerate units appear more massive and contain plant remains, rooted zones and minor carbonaceous partings.

Ross River block

The Ross River block is bounded by faults with large vertical separations which may have strike-slip displacements. The position of faults shown on Figure 5 east of Ross River townsite and south of the Canol Road is conjectural, owing to extensive surficial cover.

Early Tertiary strata in the Ross River block are exposed within a small area near its western extremity, and along and north of the Canol Road, 1.5 km further east (Fig. 5). Unlike the Lapie River block, which is covered by thick deposits of glacial and lacustrine material in areas away from the river, resistant strata in the central part of this block have only a thin veneer of surficial material.

At the western locality, scattered exposures of siltstone, sandstone, claystone and coal occur within an area 300 m by 100 m (Inset, Fig. 5). They are strongly folded and probably lie close to one of the bounding faults. Two coal seams, 3 m and 1.2 m thick, are exposed in small open cuts near Canol Road. Two other seams of similar thickness are exposed in nearby trenches and, although lack of exposure prevents definite correlation, their proximity to the excavated seams suggests they may be lateral equivalents.

FIGURE 6. *Two channels infilled with small pebble-granule conglomerates within mudstone dominated part of the sequence (81 m level) exposed on Lapie River. Channels are six to eight metres across.*

Further east a homoclinal succession, at least 400 m thick, is partially exposed along the north side of Canol Road. This sequence is largely undeformed, and dips southwest at 10 to 30°. The section, from its base, comprises a recessive, poorly exposed 200 m thick unit of massive to laminated claystone, siltstone, and minor sandstone; a more resistant 110 m thick unit of sandstone, siltstone, claystone, coal (five seams) and, in the lower part, massive to stratified units of conglomerate and sandstone up to 12 m thick; and a resistant unit, at least 100 m thick, of massive to crudely stratified and in part cross-stratified conglomerate and minor sandstone. Parts of this upper conglomeratic unit and some of the more resistant beds in the underlying unit are exposed between the road section and the bounding fault to the north.

The conglomerates are similar in character to the thicker units in Lapie River section; they range from granule to large pebble grade, with maximum clast size up to 9 cm. Individual beds may be up to 4.5 m thick, although composite bed sets may be thicker. Lenticular sandstones intercalated with conglomerates are of medium to very coarse sand grade and exhibit plane bedding and trough and planar cross-stratification. Finer grained sandstones in the more shaly parts of the section are ripple cross-laminated. In the lower parts of the section the mudrocks are commonly laminated with few plant remains, whereas in the central part of the section they tend to be massive to laminated with more abundant plant remains, rooted zones and thin carbonaceous partings.

Coal seams 0.3, 0.4, 0.65, 0.9 and 2.65 m thick were recorded at 231, 235, 241, 264 and 286 m respectively from the base of the section. Covered intervals within the central and lower units may conceal additional seams.

Age and correlation

The ages of the coal-bearing strata in this area have been determined approximately from examination of macro- and microflora. Kindle (1946) reported a Paleocene age for a collection of plant remains from the Lapie River section. Microflora examined in conjunction with this study (Hopkins, 1979) are poorly preserved, but suggest an Early or possibly Middle Eocene age for a sample collected from the basal part of the Lapie River section, and an age no younger than Eocene and probably Early Eocene or Lower Middle Eocene for two samples from the Canol Road section.

Both the Lapie River and Canol Road sections show gross coarsening upwards trends, from shale at the base to conglomerate at the top, and are of comparable thickness. Absence of marker horizons precludes direct correlation of these two sections. Correlation between the sections based on palynomorph assemblages is not possible other than to suggest a broad age equivalence, due to the small number of palynomorphs present and their poor state of preservation. Coal rank, as determined from vitrinite reflectance (measured by A.R. Cameron of the Geological Survey of Canada), is markedly higher in the Ross River area than within equivalent sediments elsewhere in the Trench. Coals from the Lapie River section are of high volatile bituminous A rank (1.0-1.25% R_o) and coals from the road section and western part of the Ross River block are respectively of low volatile bituminous (1.6-1.7% R_o) and semi-anthracite (1.9% R_o) rank. This elevation in rank suggests an abnormally high geothermal gradient during much of the burial period of these coals, probably a result of local heating related to intrusions emplaced at relatively shallow depth subsequent to their deposition. These rank variations can be used to suggest a correlation if strike-slip movement between the two blocks was relatively minor. If the two blocks were close during coalification and experienced similar thermal histories, and if most of the coalification preceded deformation, a relatively constant increase in rank with depth would be expected. This would suggest that the Lapie River sediments are younger than those in the Ross River block, and that the western coals of the Ross River block underlie or correlate with the lower part of the Canol Road section. If linear rank gradients of 0.1 to 0.2% R_o/100 m are assumed (a range which includes the highest gradients yet noted in western Canadian coals), and if the above assumptions are valid, correlations between the two sections ranging from 200 m of missing strata (if the low gradient is selected) to a slight overlap (if the high gradient is selected) are indicated. These correlations imply a minimum thickness of between 800 and 1100 m of early Tertiary strata may be present in this area.

Dawson area

The Dawson segment of the Trench (Figs. 1, 7), between South Klondike River and the Alaska border, is the largest part known to contain early Tertiary sediments. Between South Klondike and Chandindu Rivers, the north side of the Trench is poorly defined and the floor is mantled by extensively slumped Tertiary and/or Quaternary deposits (Vernon and Hughes, 1966). Bedrock exposures are rare. Northwest of Chandindu River the Trench is well-defined and varies between 2 and 5 km in width. Surficial cover is relatively thin and early Tertiary sediments are sparsely exposed over a wide area.

South Klondike River to Chandindu River

Southeast of Chandindu River early Tertiary strata were noted within the Trench at three localities. A steeply dipping (25 to 80°), faulted conglomeratic sequence at least 22 m thick is partially exposed along a drainage ditch between North and South Klondike Rivers 63°50'50"N, 138°35'00"W (Fig. 1). Exposed parts of this section are dominated by poorly sorted, massive and weakly stratified, small to very large pebble conglomerates, in beds 0.1 to 4.4 m thick, separated by rooted and organically rich mudrocks, up to a metre thick, and minor thin beds of medium- to very coarse-grained sandstone and pebbly mudstone. Thin carbonaceous horizons are present within the finer grained units. Clasts within the conglomerates are commonly moderately well rounded and are dominated by grey and green quartzite, quartz, grey siltstones, schist and minor syenite. Some clasts are sheared.

Farther northwest, along Coal Creek [a tributary of Rock Creek (Fig. 7)], the Gates Mine worked a lignite zone between 1898 and 1903 and in 1937 (McConnell, 1903; Bostock, 1938; Milner and Craig, 1973). The coal comprised a lower 0.9 m thick seam separated by 0.1 m of claystone parting from an upper 0.6-0.9 m thick seam. When visited in 1978 extensive slumping had obscured the mine entry and these seams could not be located, although soft clays and a 20 cm thick coal seam were exposed by trenching near the former mine entry. In the mine these seams were faulted near the surface and dipped southeast at from 3 to 25° (McConnell, op. cit., p. 31; Bostock, 1938).

Along the east side of Chandindu River, 3 km above its junction with Alder Creek, a very poorly exposed, nearly flat-lying sequence of conglomerate and sandstone about 105 m thick is present. Conglomerates are granule to very large pebble grade, with maximum clast size from 1 to 18 cm. Clast types are dominated by drab quartzites, schist, vein quartz and syenite. Minor claystone and siltstone beds within this sequence contain dispersed plant remains and thin carbonaceous partings.

Chandindu River to Fifteenmile River

Sediments exposed between Chandindu and Fifteenmile Rivers are moderately to steeply dipping (40-82°). At Locality 1 (Fig. 7), a continuous exposure along a slump scarp reveals a major north plunging anticline, the east and west flanks of which dip 30° and 50° respectively. Massive and stratified granule to large pebble conglomerate with lesser amounts of coarse sandstone form 80 to 90 per cent of the strata exposed in this area. An exception is a small exposure of rooted, plant-bearing claystone and siltstone along lower Thane Creek. Clasts within the conglomerates are subangular to subrounded, with maximum size from 1.5 to 9 cm. Clast types, in decreasing order of abundance, include light and dark grey quartzite, quartz, red, green and black argillites and minor grey limestone.

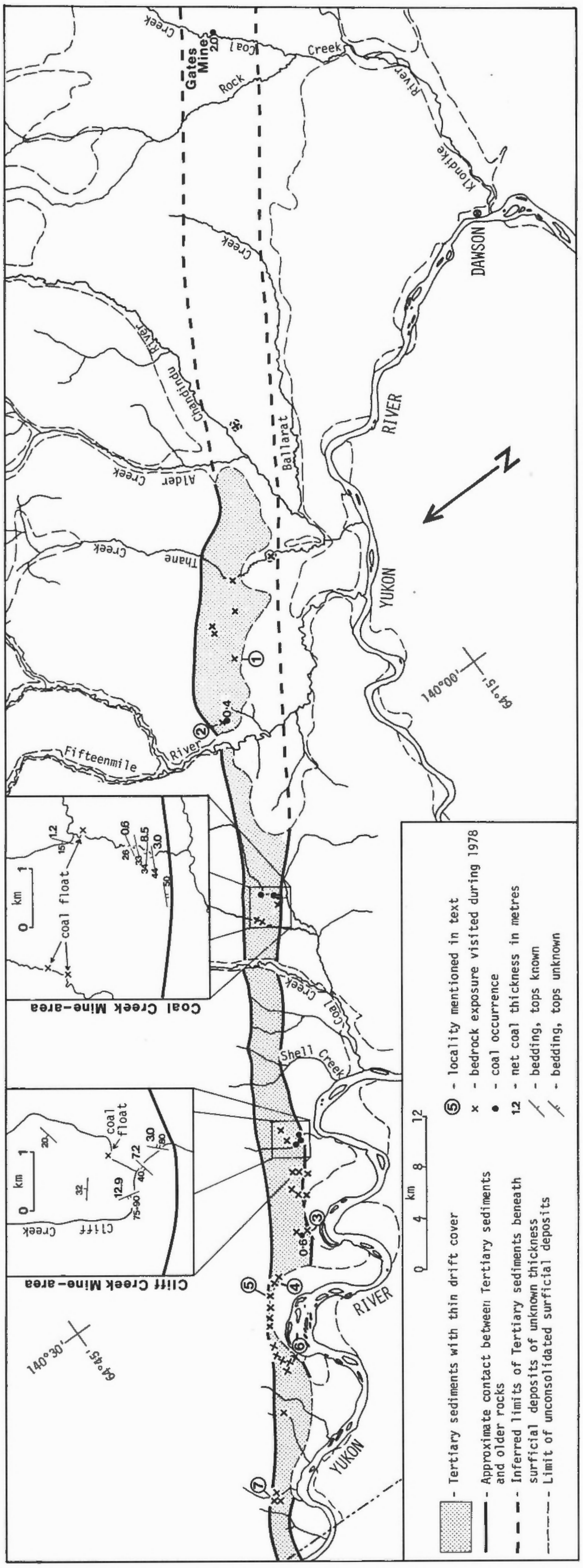


FIGURE 7. Distribution of early Tertiary sediments in Dawson area showing field localities and net coal thickness (modified from Green, 1972, Map 1284A).

At Locality 2, a slump scarp just east of Fifteenmile River, at least 200 m of monoclinal (40°S) strata are exposed. Conglomerate and sandstone beds up to 10 m thick make up most of the section. Mean clast size of the conglomerates (granule to very large pebble grade) is coarser than in exposures farther east, with maximum size up to 15 cm. Claystone, siltstone and several thin coal seams occur within recessive intervals in the lower 125 m of the sequence. The coal seams range between 5 and 40 cm in thickness and occur at the 11, 35, 45, 57, 112 and 125 m levels within the section. A light grey to white weathering claystone bed at the 100 m level proved exceptionally rich in plant remains.

Fifteenmile River to Cliff Creek

Coal seams of potential economic significance are exposed along Cliff Creek and a tributary of Coal Creek (Insets, Fig. 7). Seams at Cliff Creek were mined between 1898 and 1903, and at Coal Creek, a mine supplied a coal-fired thermal-electric plant which produced electricity for gold-dredges in the Klondike until 1914 (Green, 1977). Railways were built along both creeks to loading facilities on Yukon River, where some of the coal was shipped to Dawson for domestic use. The creek valleys in both areas are heavily treed and bedrock exposures are sparse.

On Coal Creek (Inset, Fig. 7), Tertiary strata underlie an area about 3 km wide and abut graphitic schists of the "Nasina Series" (Green, 1972) on the southwest and Precambrian and/or Cambrian volcanic rocks to the northeast. Four coal seams are exposed along the creek within 800 m of the contact with the schists.

The seam nearest the southwest limit of the Trench includes at least 3.0 m of coal with three thin claystone partings exposed along the northwest side of the creek below the old mine buildings. Workings described by McConnell (1906) may have been on this seam. In these workings, which at that time consisted of an inclined shaft 150 m in length, the seam varied between 1.2 and 3.3 m in thickness and dipped ". . . to the southeast at an angle of 45° for a distance of 210 feet (64 m) from the surface, and then (bent) round and (dipped) to the southwest." (McConnell, 1906, p. 63).

Approximately 100 m upstream, 8.5 m of coal are exposed over a 10.5 m interval. The roof of the seam is not exposed. This seam is underlain by 3.7 m of rooted, plant-bearing, light grey to cream weathering claystone, overlying 1 m of claystone with two thin coaly horizons and 3 m of massive, coarse- to very coarse-grained, pebbly sandstone. Fourteen claystone partings, 2 to 80 cm thick, occur within the seam. Resin nodules up to 1 cm maximum dimension occur singly and in places form up to 60 per cent of discontinuous 1 to 2 cm thick layers (Fig. 8). They are similar in character to resin occurrences within seams at Watson Lake and in other seams in this area.

Two hundred metres upstream, 4 m of poorly lithified, medium- to coarse-grained, pebbly sandstone overlain by 0.7 m of siltstone, claystone and an 11 cm thick coal bed are exposed on the southeast side of the creek. This is approximately the site of a tunnel reported by Collier (1903) as having been driven on a 1.5 m thick seam. No trace of the old workings or the coal seam could be found at this location. One hundred fifty metres farther upstream, near the site of a 30 m long tunnel also recorded by Collier (op. cit.), at least 0.6 m of coal (roof not exposed) underlain by claystone is exposed. Approximately 1 km upstream from this point, a seam at least 1.2 m thick, split by a 20 cm claystone parting, was exposed by trenching. Neither the roof nor the floor of this seam could be exposed, and 1.2 m is therefore a minimum thickness.

Stratigraphic relations between the coal seams are uncertain; however, the widely separated nature of the coal exposures, and the presence of coaly debris along the creek between the upper and lower exposures and in the adjacent valley to the northwest, suggests that coal may occur over a relatively thick stratigraphic interval in this area.

On Cliff Creek, Tertiary strata occupy a 4 km wide area bounded by schistose "Nasina Series" rocks on the south and Precambrian and/or Cambrian rocks to the north (Green, 1972). Three coal seams are exposed along the creek within 1 km of the contact with the Nasina schists. All are moderately to steeply dipping in contrast to gently dipping sandstone and conglomerate exposed in a structurally higher position in the central part of the Trench (Inset, Fig. 7). The more intense deformation associated with the coals may be a function of the structural incompetence of the stratigraphic interval of which they are a part and/or the localization of deformation along faults near the southern boundary of the Trench.

The first seam encountered in traversing the creek from the river is exposed on the east bank and comprises 3 m of coal with three thin claystone partings underlain by claystone. The roof of the seam is not exposed. The seam dips southeast at 80° and may be overturned. Four hundred metres upstream on the opposite bank a 7.2 m thick seam with three thin claystone partings was exposed by trenching. This seam appears to dip north at 40°, however surface creep could have affected the exposure, and this bedding attitude and hence the seam thickness may be in error. This exposure is probably the site of the "lower workings" noted by McConnell (1903, p. 32), which worked a seam about 3 m thick whose dip was ". . . much less than in the upper (workings), and in places . . . almost horizontal.".

FIGURE 8. *Resin nodules within hand specimen from 8.5 m thick seam on Coal Creek (inset, Fig. 7). Large divisions on scale at left are 1 cm.*

The seam mined in the "upper workings" of McConnell (op. cit.) is exposed 10 m above creek level on the east bank about 500 m farther upstream. Where presently exposed, this seam dips west at from 75 to 90° and may be overturned; however, in the old workings, which entered the seam at or near creek level and extended along it for over 250 m, McConnell (op. cit.) reported dips between 50 and 75°. McConnell recorded this coal zone, with partings, as over 12 m thick in some places and in the old workings, 90 m from the surface, he measured a partial section comprising 3.3 m of coal with partings. In a section measured within a trench across this zone during the course of this study, 12.9 m of coal was recorded over an 18.4 m stratigraphic interval. The trench ended in coal at its western end. Fifteen partings, four of which exceed 19 cm in thickness, are present within the seam. This section was also measured by Hopkins et al. (1975), who recorded a similar thickness and collected samples for palynological examination.

Cliff Creek to U.S. Border

Between Cliff Creek and Locality 3 (Fig. 7), exposures are limited to three small outcrops of conglomerate and sandstone along two southwest-flowing tributaries of Yukon River. In a 25 m exposure along the southeasternmost creek (Lat. 64°33'05"N; Long. 140°30'58"W) rooted and laminated claystones, siltstones and pebbly mudstones are found in association with massive and stratified granule to large pebble conglomerates. Maximum clast size in the conglomerates is 11 cm. Clasts are typically angular to subangular (unlike previous sections) and are dominated by drab grey quartzites and muscovite schists, with only minor vein quartz. Imbrication is present in one bed. Limonite nodules are common in the associated mudrocks. Bedding attitude at the three exposures visited ranged from 17 to 45°.

At Locality 3, a partially exposed sequence about 200 m thick consists mainly of conglomerate and sandstone with minor claystone, siltstone and a 1 m thick coaly horizon. The base of this section is 200 m north of the contact with Nasina schists. Conglomerate and sandstone form about equal proportions of the section. The conglomerates are of granule and small pebble grade, with maximum clast size of 3 cm. They occur in beds up to 2 m thick which are weakly stratified or cross-stratified. Larger clasts are subrounded to rounded. Sandstones are dominated by medium- to very coarse-grained, pebbly varieties, characterized by planar and trough cross-stratification, with finer grained ripple and plane bedded varieties forming only a small part of the section. Log impressions and carbonized plant fragments are present in some of the sandstone beds. The coal seam has three claystone partings totalling 30 cm and occurs near the middle of the section. Dips within the section are to the north at 13 to 40°.

Recent alluvium covers much of the Trench between Localities 3 and 5. Exposures of Tertiary strata near Localities 4 and 5 are restricted to a narrow belt near the northern bounding fault of the Tintina Zone (Fig. 7). Strata within this segment are relatively flat-lying near the centre of the Trench, generally not exceeding 10° dip, but steepen near the bounding faults. In the western part of this area, dips are up to 40° northeast near the southern fault, and between 14 and 30° northeast near the northern fault. Dip steepens to 80° near Locality 5 (Fig. 7). Resistant coarse-grained strata, predominantly granule to pebble conglomerate and sandstone, characterize this area, and in the west where dips are low form resistant pinnacles and castellated exposures.

At Locality 4, over 100 m of conglomerate and sandstone are exposed. Conglomerates in beds from 0.2 to 5 m thick make up about 60 per cent of this section. Mean clast size is from granule to very large pebble grade, although small and medium pebble conglomerate predominate. Maximum clast size is from 1 to 14 cm. Sandstones are fine- to very coarse-grained and include massive, planar and trough cross-stratified, plane bedded and ripple laminated varieties. Sandstones occur as lenses in the conglomerate and as beds up to 2 m thick.

Approximately 1 km farther northwest, at Locality 5 (Fig. 7), conglomerates are generally of coarser grade (predominantly medium and large pebble) and make up a higher proportion of the exposed beds, which occur over a stratigraphic interval of more than 200 m. Clasts are subrounded to rounded, with maximum size up to 10 cm. Conglomerates of similar grade occur in association with minor sandstones in scattered exposures along an escarpment 0.5 to 2 km northwest of this locality (Fig. 7).

At Locality 6, several isolated exposures with similar attitudes suggest the presence of at least 300 m of strata between the stratigraphically lowest exposure, about 200 m from the southern fault of the Tintina Zone, and the highest exposure in the central part of the Trench, although structural relations between some of these outcrops are uncertain. At the base of this sequence is 35 m of coarse- to very coarse-grained, massive to cross-stratified sandstone interbedded with granule conglomerate and a thin coal seam. This seam comprises 35 cm of coal and carbonaceous claystone and occurs within a recessive interval near the middle of the unit. Overlying exposures consist mainly of interbedded massive, stratified and cross-stratified conglomerate and sandstone. The conglomerates are finer-grained than at Locality 5, with mean grain size commonly in the granule and small pebble range and maximum grain size rarely exceeding 3 cm. Sandstones include massive and crossbedded, pebbly, medium- to very coarse-grained varieties and some finer grained ripple and plane bedded varieties. Casts and carbonized remains of logs and branches are present in some beds.

At Locality 7, 4 km east of the Alaska border, conglomerates and sandstones similar to those described elsewhere are exposed along both sides of a south-flowing creek (Fig. 6). Dips within this sequence are northeast at from 25 to 40°. A partially exposed section about 140 m thick occurs on the west side of the creek. Approximately 75 per cent of this section is conglomerate. Mean grain size is from granule to large pebble grade, with small pebble conglomerates being most common. Maximum clast size is 1 to 5 cm. Clasts tend to be subrounded and are composed predominantly of green and black mica schists, vein quartz and quartzite. Sandstones are typically medium- to very coarse-grained, and are either massive or cross-stratified. They occur as lenticular interbeds within the conglomerates and as beds up to 2 m thick.

Thickness and correlation

The total thickness of Tertiary strata within the Dawson segment of the Trench and their lateral and vertical relationships can only be known in general terms with the limited exposures available. Studies along Seventymile River in adjacent Circle Quadrangle of Alaska (Prindle, 1913) suggest the Tertiary succession there is approximately 900 m in thickness, about equally divided between an "argillaceous sandy and lignitic" lower portion and an upper "conglomeratic" portion (Prindle, op. cit., p. 33). Mertie (1930, 1937) considered 900 m a minimum thickness, but did not venture any greater estimate owing to the structural complexity of the sequence.

The most extensive exposures in the Dawson area occur between Localities 3 and 6 (Fig. 7). Sections measured at Localities 3, 4 and 6 are lithologically similar and may be lateral equivalents. Strata at Locality 5 are coarser and, if intervening structural complications are minor, probably overlie these sections. A minimum combined thickness of 500 m is indicated for these exposures.

Vitrinite reflectance (R_o) determinations on coal seams and coaly material from the Dawson segment of the Trench generally fall in the 0.35 to 0.45 per cent range. Exceptions are the Coal Creek seams, which are slightly higher in rank averaging about 0.5 per cent, and the seam at Locality 3, which has a reflectance of 0.74 per cent. If rank at all localities is assumed to be a result of burial under a uniform geothermal gradient, and if most of the coalification preceded deformation, the relative stratigraphic position of localities would be from base: Locality 3; Coal Creek seams; Locality 6; and the Cliff Creek seams. This suggests no upward gradation to coarser clastics as noted by Prindle (op. cit.), and a total thickness in the order of 850 m. A more probable alternative is that rank has been complicated by different amounts of sedimentary loading, local variation in geothermal gradient, and possibly juxtaposition of areas with different thermal histories through strike-slip faulting and therefore that coal rank is not a meaningful indicator of stratigraphic position.

The absence of conglomerate exposures adjacent to coal occurrences on Cliff and Coal Creeks suggest these seams are associated with a relatively thick recessive sequence of finer-grained clastics. The presence of conglomerate and sandstone in a position structurally well above the coal on Cliff Creek suggests that Prindle's concept of a lower recessive sequence overlain by a conglomeratic unit may also be valid for the Dawson area. If 200 m is allowed for the thickness of the recessive unit on Cliff and Coal Creeks, a minimum total thickness of 700 m is indicated for the Tertiary succession, and this figure could be considerably higher.

Age

The sediments along the Dawson segment of the Trench were first referred to the Eocene by Knowlton (in Collier, 1903) on conifer remains from the Coal Creek mine. Later work by Hollick (1936) on macroflora from the Alaska portion of the Trench suggested both Late Cretaceous and Eocene ages and King (in Hollick, 1936), in the absence of more detailed evidence, inferred continuous sedimentation from the Late Cretaceous to the Eocene. A latest Cretaceous to early Tertiary age was also indicated by angiosperm leaf fragments and pollen collected along the lower part of Thane Creek 6 km southeast of Locality 1 (Hueber, in Green, 1972).

Recent collections from the coal measures along Coal and Cliff Creeks confirm the initial Eocene assignment of Knowlton. Microflora from the Coal Creek mine examined by Rouse (in Green, 1972) indicated a Tertiary, probably Eocene age, and the occurrence of Metasequoia occidentalis in a collection from the "upper workings" on Cliff Creek indicates a Paleocene to mid Miocene age (Hueber, in Green, 1972).

Microflora in later collections from both the "upper" and "lower workings" on Cliff Creek narrow Hueber's assignment to a probable late Eocene age (Hopkins et al., 1975).

If, as suggested previously, there is an upward gradation to coarser clastics within the Tertiary section, most of the strata outcropping along the Dawson segment of the Trench overlie the coal measures and are, therefore, of Eocene or later age. They are thus age equivalents of sequences exposed at Ross River and Watson Lake. The possibility that some of the strata are older cannot be rejected, however, given the sparse structural control and limited evidence of stratigraphic position.

Indian River area

Tertiary strata are exposed south of the Trench along Indian River and its tributaries, Ruby and McKinnon Creeks, and further west along Yukon and Sixtymile Rivers (Fig. 1) (Green, 1972; Bostock, 1942; Tempelman-Kluit, 1974; Milner, 1978).

These strata are lithologically similar to the Trench fill, and include moderately to well-indurated conglomerates, sandstones and thin coal seams, intercalated with and overlain by volcanic rocks. One of the seams, along Ruby Creek, was mined briefly during 1902 (McConnell, 1906). Exposures along McKinnon and Ruby Creeks in the vicinity of this old mine were examined briefly during the coarse of this study. Bedrock exposures in the area are rare.

The majority of the exposed rocks are quartz pebble conglomerates which have been prospected for gold at various times in the past, including a 1975 drilling program along McKinnon Creek. Clasts are predominantly vein quartz with minor dark grey to black schist and other metamorphic fragments. They are moderately to well rounded and rarely exceed 6 cm maximum dimension with mean clast size generally less than 3 cm. Clasts rarely form more than 60 per cent of the rock, the matrix being coarse- to very coarse-grained sandstone. Medium- to very coarse-grained, quartzose, massive sandstone is a minor component of the exposed strata.

At the old mine site on Ruby Creek (Lat. 63°40'06"N, Long. 139°14'14"W), a 1.05 m thick coal seam underlain by claystone is exposed. Milner (1978) traced this seam for 0.8 km and reported a northwest dip of 10°. Conglomerates are exposed a short distance above the seam and a thick basaltic flow overlies it by about 35 m. Vitrinite reflectance measurements on the coal, determined by S. Creaney of the Geological Survey, are about 3 per cent, indicating extreme thermal upgrading, possibly due to a nearby dike which fed the overlying flows. Another coal seam was intersected during 1975 drilling on McKinnon Creek; however, no details on depth, thickness and location are available (Milner, 1978).

The sedimentary rocks and the associated and overlying volcanic rocks in the Indian River area are nearly flat-lying, with dips of 10° or less. The volcanic rocks are part of the Carmacks Group which is elsewhere locally up to 1000 m in thickness (Tempelman-Kluit, 1974). In the Ruby Creek area, the lavas reach a maximum thickness of 500 m on Haystack Mountain. At a maximum, the Carmacks Group spans late Eocene to Miocene time (Bostock, 1936; Tempelman-Kluit, 1974). A more precise age range awaits dating of plant remains in the underlying strata, which in the Ruby Creek area are too thermally metamorphosed to contain recognizable plant remains. These strata could be correlatives of the Trench fill, although Green (1972, p. 104) avoids this interpretation, suggesting the latter are ". . .restricted both in source area and sedimentation to the topographic depression along Tintina Trench".

DEPOSITIONAL SETTING

Physiographic depressions suitable for the accumulation and preservation of clastic detritus existed within parts of the Trench and on the adjacent land surface during the early Tertiary. Such depressions may have formed within grabens as isolated basins restricted to small segments of the Trench, or as a series of interconnected basins occupying larger segments. In the latter case, parts of the Trench may have been the site of trunk streams draining the surrounding uplands. The basins were probably relatively narrow and elongate parallel to the Trench, as they are directly related to dip-slip movement along faults within it. An exception may be the Watson Lake area, where there is a change in trend in the Tintina-Rocky Mountain Trench System and possibly more widespread deformation, subsidence and basin filling.

Subsidence within the Trench through dip-slip movement kept pace with deposition in areas where the early Tertiary section is thick. The adjacent land surface was relatively stable during this period, and sediments which accumulated in lowland areas there are probably thin in comparison to Trench deposits.

The Tertiary fill of Tintina Trench and related basins is best interpreted as the product of deposition in fluvial and lacustrine environments. Identifiable sub-environments include lakes, alluvial fans, fan deltas, braided and (?) meandering streams and associated flood plain environments. No marine influence is apparent in any of the sections examined.

The fining and thinning upwards sequences exposed in the Watson Lake area are atypical of strata exposed within the Trench, sensu stricto. They resemble point bar sequences produced by "meandering" streams (Allen, 1965) and as such may represent deposits of intermediate to high sinuosity streams. The absence of identifiable lateral accretion sets does not preclude a point bar origin as these may have low dips (Nigman and Puigdefabregas, 1978) or be obscured by smaller scale structures (Rust, 1978). Frequent flood events, affecting the overbank - floodplain environment, are indicated by the high ash content in some of the Watson Lake coals, and by the abundance of mudrocks in the exposed parts of the sequence. Local development of crevasse splays is indicated by the preservation of tree stumps, in growth position, within homogeneous silty mudstone at Locality 1 in the Watson Lake area (Fig. 2).

Extensive laminated mudrocks at the base of the Canol Road and Lapie River sections in the Ross River area are best interpreted as lake deposits. The development of coarsening upwards sequences capped by conglomeratic channel fill (Fig. 6) and rooted flood plain deposits, within the lowermost hundred metres of the Lapie River section, is consistent with development of small-scale deltas at the mouths of small streams or rivers. Coarser grained parts of both sections in the Ross River area can be interpreted as products of rapid progradation of (wet) alluvial fans and fan deltas (Holmes, 1965; McGowen, 1970) into and across the lacustrine facies. Relatively high stream gradients are indicated by the massive to crudely bedded character of the conglomerates. Coal found in close association with these conglomerates, in both the Lapie River and Canol Road sections, probably formed in mid to distal fan environments (cf. Heward, 1978) possibly during degradational phases of fan development.

Conglomerates and conglomeratic sandstones forming the greater part of the outcrop belt in the Dawson segment of the Trench were deposited in alluvial fan and associated braided stream environments. By analogy with the Van Horn Sandstone (McGowen and Groat, 1971) massive and weakly stratified conglomerates represent proximal fan deposits; interbedded conglomerates and sandstones represent mid fan deposits and sandstone dominated parts of the sequence, characterized by abundant cross-stratification, may represent distal fan and associated braided fluvial deposits. Lack of coarse clastics in association with the coals at Cliff and Coal Creeks suggests they were deposited in areas remote from major river channels or fan aprons. Whether these coals formed from swamps extending across most of the valley floor or from swamps restricted to limited parts of the floodplain is uncertain and can only be resolved by extensive subsurface exploration. The presence of carbonaceous claystone partings within these coal seams indicates that infrequent floods periodically affected the local swamp environments. Bentonitic claystone partings may have originated in part as volcanic ash, although analysis of these clays to support such an origin has not as yet been completed.

The climate of northern Yukon during deposition of coal-bearing strata within the Trench was temperate to warm temperate (Hopkins and Norris, 1974). The existence of extensive vegetation is indicated by the presence of coal seams, abundant plant remains and root zones. The abundance of resin in some of the Tintina Trench coals and in Tertiary coals in general is related to the abundance of conifers in flora of that age (Stach et al., 1975). Assemblages of macro- and microflora from Trench sediments suggest that both conifers and deciduous varieties were important (Hollick, 1936; Hopkins et al., 1975; Hopkins, 1978a, b; 1979). Maceral analysis of the coals indicates a high preservation of woody material with only minor amounts inertinite, suggesting that environmental events related to inertinite production, such as forest fires, had a low rate of occurrence.

The general coarsening upward trend observed in the Ross River area and inferred for the Dawson area may be related to increased tectonic activity and renewed movement along faults within the Trench during deposition of the younger sediments.

A high degree of lateral variability can be expected in the character of sedimentary rocks accumulated within linear, laterally restricted intermontane basins, such as those represented by the Trench fill. This is evident from the lenticular nature of rock units in the better exposures and in the old workings on coal seams along Cliff Creek (McConnell, 1903). Thick coal seams other than those noted in the Cliff and Coal Creek areas may well be concealed within the trench sediments, but can be expected to be lenticular and of limited areal extent.

COAL QUALITY

Channel samples were collected from all coals examined in the field and submitted to proximate, sulphur and calorific value analyses. Vitrinite reflectance was determined on composite samples from each seam and maceral composition was determined on selected samples from each coal area by A.R. Cameron and S. Creaney of the Geological Survey.

Coals from each area have a distinctive rank. Watson Lake coals are of lignite A and B ranks according to the ASTM classification. Dawson coals cover the range lignite A to subbituminous A and Ross River coals range from subbituminous A to medium volatile bituminous B according to proximate analysis and from high volatile A bituminous to semi-anthracite according to vitrinite reflectance.

Differences in the rank parameter calculated using proximate analysis and vitrinite reflectance are probably attributable to weathering of samples. Weathering has been shown to produce a substantial increase in volatile matter content in coals (and a corresponding decrease in fixed carbon content) which may range up to 20 per cent (Stach et al., 1975). Vitrinite reflectance is generally less affected by weathering, although some variation can be expected depending on conditions at the outcrop and is, therefore, a more accurate rank parameter for weathered coals. Variation in vitrinite reflectance due to weathering is unlikely to be more than ± 0.1 per cent in the higher rank coals and normally this range would be less than ± 0.05 per cent (Creaney, pers. com., 1979). The use of vitrinite reflectance as a rank parameter is generally restricted to coals which have reflectances of greater than 0.35 per cent.

Figure 9 is a plot of vitrinite reflectance versus fixed carbon (d.a.f.) for coals from each area. Also shown is McCartney and Teichmüller's (1972) curve derived from unweathered European coals. Samples from the Ross River block and some samples from the Dawson area show markedly lower fixed carbon contents than fresh European coals of equivalent rank. Part of this variation may result from differences in petrographic composition; however, most of the variation is probably a result of weathering. Fixed carbon losses of from 7 to 21 per cent are evident in coals from the Ross River block and a loss of approximately 12 per cent is evident in the sample from Gates Mine in the Dawson area, although most of the Dawson coals fall near the curve. Some of the Watson Lake coals are also undoubtedly weathered, however they fall into the unreliable portion of the reflectance curve and thus their degree of alteration is uncertain.

The compositions of representative coals from the three coal areas in terms of the major maceral groups are shown in Table 1. The vitrinite-huminite group is derived mainly from wood and bark and the exinite group from remains of spores, pollen, cuticles and resin. The semi-inertinite and inertinite groups are derived through oxidation and resultant carbon enrichment of plant material during deposition, which may occur during dry periods or forest fires in the peat swamps. With the exception of coals from the Ross River block, all have very high vitrinite-huminite contents and a marked lack of semi-inertinite and inertinite. This suggests very good conditions for preservation within the peat swamps with a high water table and few periods of drying. Conditions during formation of the Ross River block coals must have been drier, resulting in the higher semi-inertinite and inertinite contents. This may relate to their proposed origin in swamps in a mid to distal fan environment, which would result in better drainage, periods of drying and occasional fires in the peat swamps. The 100 per cent vitrinite recorded for the single sample from the Lapie River block suggests the thin lenticular seam it represents is the remains of a single log. Resin or resinite, a member of the exinite group, is a conspicuous component of nearly all coals in the Watson Lake and Dawson areas (Fig. 8) and may have occurred in similar quantities in the Ross River coals, although the present high rank of the Ross River coals renders resinite indistinguishable from other macerals.

TABLE 1

Maceral Composition – Tintina Trench Coals

Area	Locality	Net Coal Thickness (m)	Macerals (MMF) Vitrinite-Huminite (%)	Exinite (%)	Semi-Inertinite (%)	Inertinite (%)
Watson Lake	2 (Fig. 2)	0.37	89.0	10.0	0.2	0.8
Ross River	Ross River Block (west)	3.00	59.8	0.0	30.6	9.6
Ross River	Ross River Block (east)	2.65	75.4	0.0	11.7	12.9
Ross River	Lapie River Block	0.30	100.0	0.0	0.0	0.0
Dawson	2 (Fig. 7)	0.38	94.2	5.4	0.0	0.2
Dawson	Coal Creek	8.53	95.2	3.8	0.2	0.8
Dawson	Coal Creek	1.25	96.6	3.4	0.0	0.0
Dawson	Cliff Creek	12.94	91.6	7.6	0.4	0.4
Dawson	Cliff Creek	7.20	92.6	6.6	0.2	0.6

TABLE 2

Coal Quality – Watson Lake Area

Locality[1]	Lat(N)	Long(W)	Position in Section (m above base)	Net Coal Thk. (m)	Proximate Analysis (%) As Rec'd Mois.	Equil. Mois.	Ash[2]	Volatile[2] Matter	Fixed[2] Carbon	Sulphur %[2]	Calorific[2] Value (MJ/kg)	Vitrinite[3] Reflectance (Ro%)	Rank Ro[4]	Proximate[5]
1	60°13'35"	129°06'15"	21.2	0.60	31.9	30.0	15.1	32.1	20.9	.74	12.55	0.32	lig	ligA
1	60°13'35"	129°06'15"	50.8	2.10	31.9	15.0	41.5	18.1	8.5	.45	5.81	0.26	lig	ligB
1	60°13'35"	129°06'15"	57.9	0.45	14.0	21.1	38.7	30.6	9.6	1.40	8.55	0.26	lig	ligB
1	60°13'35"	129°06'15"	71.2	0.40	40.7	30.0	7.5	30.6	21.2	.62	12.72	0.31	lig	ligA
1 km N of 1	60°14'09"	129°07'10"	0.6	0.20	28.7	26.2	29.3	27.5	14.5	.59	9.78	0.28	lig	ligA
2	60°21'15"	129°13'15"	0.0	0.37	38.8	29.4	13.8	28.2	19.2	.37	12.24	0.23	lig	ligA
0.6 km NW of 2	60°21'24"	129°13'45"	2.5	0.34	21.1	27.6	7.0	39.6	25.8	.54	17.44	0.30	lig	ligA
3	60°01'56"	128°52'36"	3.0	2.00	44.0	29.3	5.7	30.2	20.1	.16	15.01	0.21	peat	subC
1 km SE of 3	60°01'43"	128°51'36"	0.0	0.30	49.3	22.7	6.2	27.2	17.3	.15	11.04	0.13	peat	ligA
4	60°01'38"	128°45'06"	0.0	1.50	43.1	24.9	4.7	31.6	20.6	.17	12.94	0.11	peat	ligA
6	60°06'42"	128°50'24"	0.1	0.65	32.2	21.8	12.7	32.7	22.4	1.25	14.69	0.30	lig	subC

[1] see Figure 2 for locations
[2] calculated using higher of "as received" or "equilibrium" moistures
[3] maximum reflectance in oil-mean of 50 readings
[4] determined from vitrinite reflectance using chart in Stach et al. (1975, p. 42)
[5] determined using ASTM methods

TABLE 3

Coal Quality – Ross River Area

Locality[1]	Lat(N)	Long(W)	Position in Section (m above base)	Net Coal Thk. (m)	Proximate Analysis (%)					Sulphur %[2]	Calorific[2] Value (MJ/kg)	Vitrinite[3] Reflectance (Ro%)	Rank	
					As Rec'd Mois.	Equil. Mois.	Ash[2]	Volatile[2] Matter	Fixed[2] Carbon				Ro[4]	Proximate[5]
Lapie R. block	61°57'28"	132°35'33"	70.0	0.30	3.4	3.7	10.4	28.4	57.5	.80	29.66	1.06	hvAb	hvAb
Ross R. block (west)	61°58'29"	132°32'29"	0.1	3.00	11.4	6.8	16.5	20.6	51.5	.34	23.32	1.86	lvb	mvb
Ross R. block (west)	61°58'29"	132°32'19"	0.2	3.02	10.5	6.5	20.1	22.9	46.5	.31	22.55	1.87	lvb	mvb
Ross R. block (west)	61°58'29"	132°32'19"	0.2	1.20	15.1	9.8	25.7	21.0	38.2	.31	17.83	2.03	sa	mvb
Ross R. block (west)	61°58'29"	132°32'19"	0.1	1.20	11.4	6.6	10.6	20.0	58.0	.55	26.30	1.96	sa	lvb
Ross R. block (east)	61°58'09"	132°29'58"	241.0	0.65	11.7	7.2	20.9	25.6	41.8	.33	20.09	1.70	lvb	hvCb
Ross R. block (east)	61°58'09"	132°29'58"	264.0	0.90	21.1	16.1	31.9	18.4	28.6	.23	13.28	1.51	lvb	mvb
Ross R. block (east)	61°58'09"	132°29'58"	286.0	2.65	8.0	6.6	11.1	22.8	58.1	.29	25.94	1.56	lvb	mvb

[1] see Figure 5 for locations
[2] calculated using higher of "as received" or "equilibrium" moistures
[3] maximum reflectance in oil-mean of 50 readings
[4] determined from vitrinite reflectance using chart in Stach et al. (1975, p. 42)
[5] determined using ASTM methods

TABLE 4

Coal Quality – Dawson Area

Locality[1]	Lat(N)	Long(W)	Position in Section (m above base)	Net Coal Thk. (m)	Proximate Analysis (%)					Sulphur %[2]	Calorific[2] Value (MJ/kg)	Vitrinite[3] Reflectance (Ro%)	Rank	
					As Rec'd Mois.	Equil. Mois.	Ash[2]	Volatile[2] Matter	Fixed[2] Carbon				Ro[4]	Proximate[5]
Klondike R.	63°59'50"	138°35'00"	2.0	0.10	31.5	32.7	19.3	27.3	20.7	.39	11.37	0.42	subC	ligB
Gates Mine	64°08'04"	138°56'32"	0.0	0.20	24.9	23.6	16.8	31.5	26.8	.55	16.49	0.40	subC	ligB
2	64°24'48"	139°50'22"	11.6	0.38	26.7	21.2	6.5	34.5	32.3	.26	18.05	0.58	subA	subC
2	64°24'48"	139°50'22"	47.1	0.32	38.7	29.7	11.2	25.7	24.4	.24	12.00	0.42	subC	ligA
2	64°24'48"	139°50'22"	112.1	0.28	36.2	32.7	9.6	27.2	27.0	.29	13.11	0.42	subC	ligA
Coal Creek	64°27'53"	140°06'02"	0.0	1.25	20.8	17.1	26.9	26.1	26.2	.57	14.59	0.54	subA	subC
Coal Creek	64°27'27"	140°06'53"	0.1	0.60	29.0	20.2	10.9	28.2	31.9	.48	17.20	0.47	subB	subB
Coal Creek	64°27'21"	140°07'13"	7.6	8.53	16.8	18.2	19.6	29.8	32.4	.56	18.24	0.46	subB	subB
Coal Creek	64°27'19"	140°07'18"	0.1	3.00	19.5	16.5	8.3	35.8	36.4	1.47	17.60	0.53	subA	subC
Cliff Creek	64°32'19"	140°27'12"	0.1	2.78	31.4	19.8	6.6	31.7	30.3	1.13	16.76	0.38	lig	subC
Cliff Creek	64°32'29"	140°27'19"	0.0	7.20	29.4	21.1	3.6	32.6	34.4	.69	18.27	0.46	subB	subC
Cliff Creek	64°32'45"	140°27'37"	0.0	12.94	27.5	21.2	11.4	31.4	29.7	.65	15.45	0.36	lig	subC
3	64°34'54"	140°35'20"	32.6	0.61	19.0	15.4	14.9	30.7	35.4	.53	17.91	0.74	hvBb	subB

[1] see Figure 7 for locations
[2] calculated using higher of "as received" or "equilibrium" moistures
[3] maximum reflectance in oil-mean of 50 readings
[4] determined from vitrinite reflectance using chart in Stach et al. (1975, p. 42)
[5] determined using ASTM methods

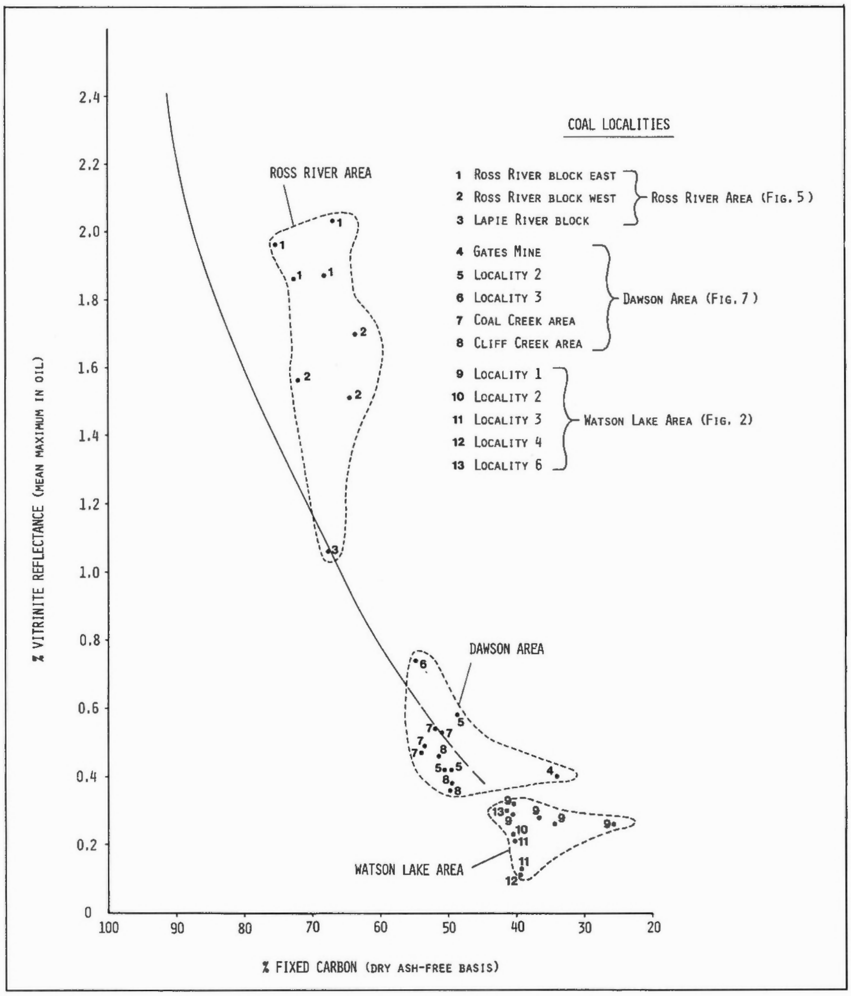


FIGURE 9. Vitrinite reflectance versus fixed carbon content for Tintina Trench coals. Solid line is curve of McCartney and Teichmüller (1972) derived from unweathered European coals. Departure from curve is probably a result of weathering (see text).

"As received" and "equilibrium" moistures, proximate analysis, sulphur content, calorific value and vitrinite reflectance for seams from the Watson Lake, Ross River and Dawson coal areas appear in Tables 2, 3 and 4 respectively. Values shown for the thicker seams are weighted averages from two ore more incremental samples. Also shown is rank determined using both proximate analysis and virtrinite reflectance. The moisture content of weathered surface coal does not, except under ideal conditions, reflect the moisture content of the same coal in an unweathered state. As the moisture content is critical in determining the ranks of coals with less than 69 per cent fixed carbon (d.a.f.) using the ASTM classification scheme, rank determinations based on surface samples must be viewed only as general approximations. "Equilibrium" moistures were determined on samples crushed to -16 mesh as prescribed by ASTM procedures. Crushing the samples apparently reduces pore volume from that of fresh coaol, as "equilibrium" moistures in the samples analyzed are generally lower than bed moistures normally found in fresh coals of this rank, which may range from 25 per cent, for subbituminous coal, to 75 per cent, for low-grade lignites (Stach et al., 1975, p. 36, 42). "As received" moistures were determined simply from weight lost in drying the samples, which were sealed at outcrop to prevent moisture loss, and are generally higher than "equilibrium" moistures determined on the same samples. In Tables 2, 3 and 4 the higher of the two moisture values was considered the closest approximation to the true bed moisture and the proximate, sulphur and calorific values listed were calculated using the higher moisture. The rank appearing under "proximate"; in these tables was determined using only the "equilibrium" moisture, in accordance with the ASTM practice of equating "equilibrium" with "bed" moisture.

Sulphur content in all coals sampled is low, in common with most western Canadian coals. Sulphur generally ranges between 0.2 and 0.8 per cent, and exceeds 1 per cent only at Localities 1 and 6 in the Watson Lake area (Fig. 2) and in two seams at Cliff Creek and Coal Creek in the Dawson area (Figs. 1, 7).

Calorific values range from 11MJ/kg, for the lower ash lignites in the Watson Lake and Dawson areas, to nearly 30MJ/kg for the bituminous coal near Ross River. The calorific values reported for the lower rank coals are probably somewhat higher than can be expected from unweathered samples, because of the previously discussed inaccuracy in determining moisture content. The calorific value of fresh Ross River coal may be somewhat higher than reported in Table 3, due to the severe weathering of some of the samples.

Ash contents of the coals are variable, both between localities and within individual seams. Inorganic matter within the seams appears to include both waterborne material, introduced during periodic flooding of the peat swamps and, in the Dawson area at least, minor airborne material, principally volcanic ash, carried by winds from distant sources. The proportion of waterborne material is related mainly to local environmental elements, such as proximity to channel systems, frequency and magnitude of flooding and paleotopography; whereas the rate of accumulation of volcanic ash is dependent on the amount and proximity of volcanic activity and is largely unaffected by the local environment. In the laterally restricted, linear depositional basins inferred for coal-bearing strata of the Tintina Valley, environmental elements probably changed rapidly over relatively small distances, and thus the variable ash contents noted between localities in Tables 2, 3 and 4 are to be expected. Fluctuations in volcanic activity with time would also contribute to variation in ash content between seams at different stratigraphic levels and between different levels of individual seams.

Figures 10 and 11 show the variation in quality and the distribution of partings within seams along Coal Creek and Cliff Creek in the Dawson area. The thin yellow weathering bentonitic partings within these seams may be in part of volcanic origin, whereas the thicker, grey to brown weathering claystone partings probably represent deposition of suspended material from floodwaters. Two seams along Cliff Creek and one along Coal Creek display remarkably low and consistent ash contents, suggesting they were well protected from incursions by floodwaters. The thickest coal zones in both areas contain numerous partings and exhibit higher and more varied ash contents, suggesting less protected depositional settings with periodic flooding.

With the exception of some very high ash coals in the Watson Lake area, all coals examined in this study could provide acceptable fuels for thermal-electric generation, should sufficient resources be defined. Ross River coals would be the preferred fuel because of their high calorific value, moderate ash levels and freedom from partings; followed by the Dawson coals, which are of lower calorific value but have low to moderate ash and occur within relatively thick zones. Watson Lake coals, with their low calorific value and variable ash contents, are the least attractive fuel source.

COAL RESOURCE POTENTIAL

Coal resources refer to coal contained in seams that occur in the ground within specified limits of thickness and depth from surface. Arbitrary limits have been set for these parameters and on this basis, together with some other considerations such as quality and structural complexity, resources can be subdivided into those of immediate and future interest (Energy, Mines and Resources, 1977). Resources can also be subdivided into "measured", "indicated", "inferred" and "speculative" categories based on their degree of geologic control and hence their assurance of existence. The density of geologic control required for each category is a function of the structural complexity of a deposit. Criteria for each category at several levels of structural complexity have been established by Energy, Mines and Resources (op. cit.).

Coals along Tintina Trench are structurally complex and, with the exception of the Ross River area, are of low rank. Both factors restrict potential exploitation techniques and the former greatly increases the exploration expense required to delineate the resources. It is unlikely that coal seams of sufficient continuity and thickness will be defined to allow underground mining with current technology on anything but a very small scale. Surface mining is the only currently practical alternative in most areas and, because of the probable small extent of suitable deposits at any one locality, it will also be restricted to small scale operations.

Watson Lake area

Several factors limit the size of potential coal deposits in the Watson Lake area. These include structural complexity, surficial cover and coal quality and geometry.

Structural complexity

Coal-bearing strata are extensively deformed by tectonic and glacial processes in surface exposures. Recent drilling in parts of the area encountered thick coal intersections which, based on tentative correlations between relatively widely spaced holes (1-1.5 km), may be only slightly or moderately deformed. In view of the laterally variable nature of the coal-bearing strata and the difficulty in recognizing bedding in the core, broad correlations which indicate essentially flat-lying strata could be in error and deformation in the subsurface could be more like that seen in surface exposures. If moderate to high subsurface deformation prevails, variable and steep dips will restrict the volume of near surface coal at any one locality and delineation of mineable deposits will require extensive close-spaced drilling.

Surficial cover

Glacial and alluvial cover is thick and widespread in many parts of Liard Plain. Unless very thick seams are defined, unfavourable strip ratios will restrict surface mining to areas where surficial cover is thin.

Coal quality and geometry

Coal seams are of lignite A and B rank. Their low heating value coupled with high ash in some seams will limit practical mining depths and strip ratios. The depositional setting of the coals suggests individual seams will prove to be lenticular and laterally restricted.

For a deposit to be mineable, favourable conditions of low dip, thick seams and thin surficial cover must be met. The prospects for such conditions occurring over large enough areas to define major deposits in the Watson Lake area are not good. Much subsurface exploration will be required to delineate mineable deposits.

Ross River area

Small, potentially mineable coal deposits are present in the Ross River area. Along the Canol Road section of the Ross River block (Fig. 4) strata dip at about 30° and include a 2.7 m thick seam of bituminous coal. If this seam is assumed continuous in thickness and inclination for the 1 km strike length between the bounding faults, inferred resources would be as given in Table 5. Other seams observed in this section are too thin to meet current resource criteria, although the possibility exists that additional seams are present within the covered intervals.

TABLE 5

Inferred Resources, Canol Road Section, Ross River Block

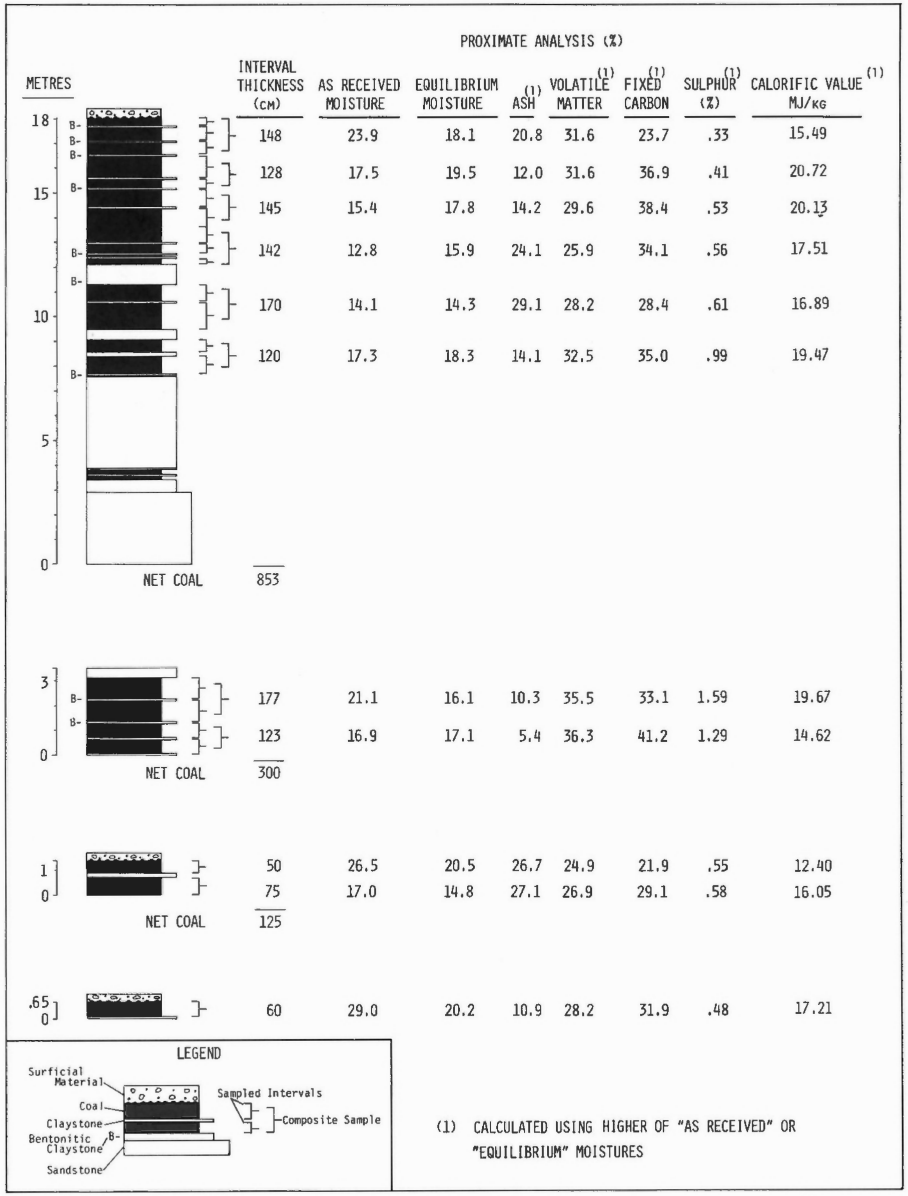
Depth of cover (m)	Inferred Resources kilotons
0 - 50	370
0 - 100	740
0 - 150	1100

Additional resources are possible at the western end of the Ross River block (Inset, Fig. 4); however, the deformed nature of the seams at the surface prevents a meaningful resource estimate. A small amount of the easily accessible coal has already been removed from this locality. Proximity to the bounding faults and the small area underlain by potentially coal-bearing strata suggests resources at this locality are small.

Some potential exists for the discovery of coal seams within covered parts of the Lapie River section; however, the extensive surficial cover away from the river suggests potential resources for surface mining are limited.

Dawson area

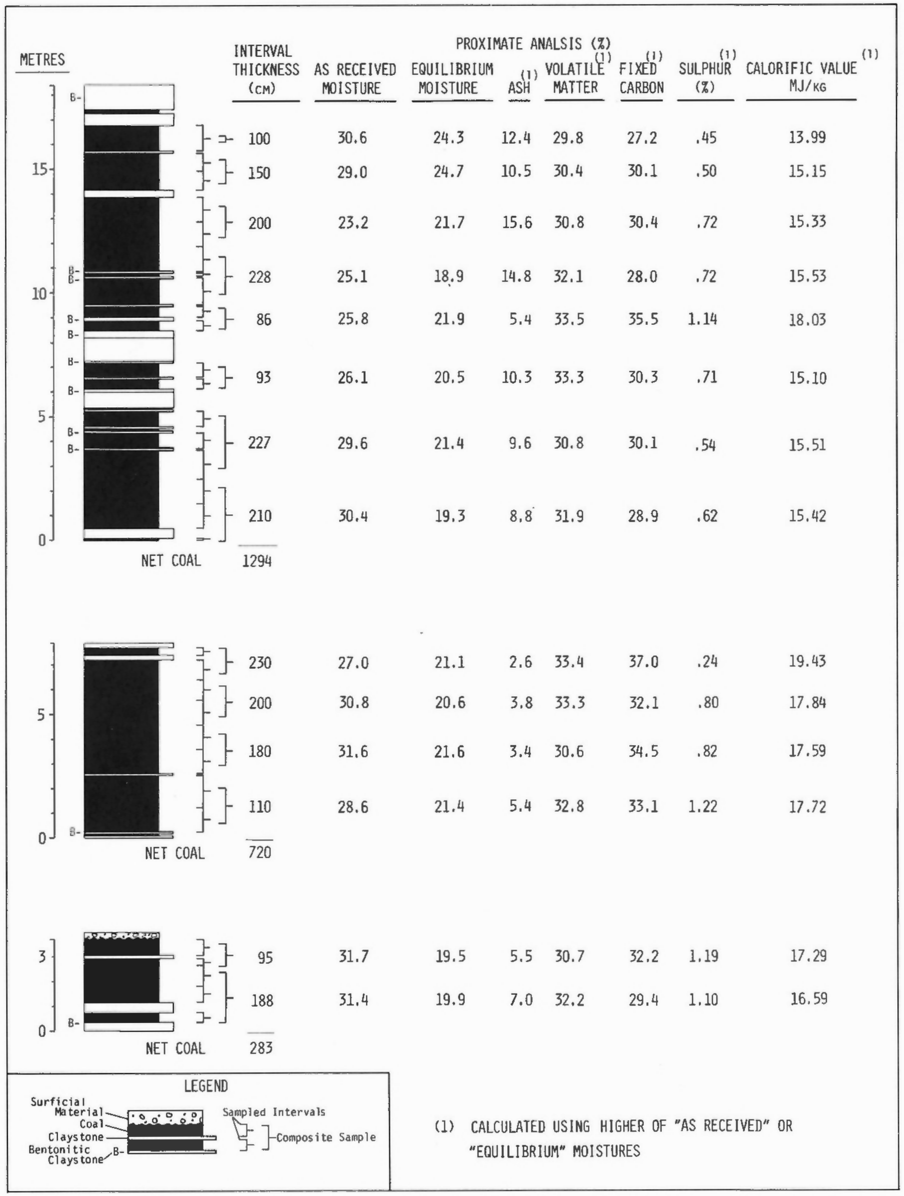
The Dawson area contains the thickest coal seams observed within the Trench. In small areas at least, conditions for preservation of vegetation in peat swamps were ideal, and hence the potential for the discovery of additional thick seams within the recessive strata along Cliff and Coal Creeks and within equivalent strata concealed elsewhere within the Trench is good. The steep dips and structural complexity of some of these seams, however, limits the volume of near surface coal and suggests mineable deposits at any one locality will be small.



	INTERVAL THICKNESS (cm)	AS RECEIVED MOISTURE	PROXIMATE ANALYSIS (%)					
			EQUILIBRIUM MOISTURE	ASH (1)	VOLATILE (1) MATTER	FIXED (1) CARBON	SULPHUR (1) (%)	CALORIFIC VALUE (1) MJ/kg
	148	23.9	18.1	20.8	31.6	23.7	.33	15.49
	128	17.5	19.5	12.0	31.6	36.9	.41	20.72
	145	15.4	17.8	14.2	29.6	38.4	.53	20.13
	142	12.8	15.9	24.1	25.9	34.1	.56	17.51
	170	14.1	14.3	29.1	28.2	28.4	.61	16.89
	120	17.3	18.3	14.1	32.5	35.0	.99	19.47
NET COAL	853							
	177	21.1	16.1	10.3	35.5	33.1	1.59	19.67
	123	16.9	17.1	5.4	36.3	41.2	1.29	14.62
NET COAL	300							
	50	26.5	20.5	26.7	24.9	21.9	.55	12.40
	75	17.0	14.8	27.1	26.9	29.1	.58	16.05
NET COAL	125							
	60	29.0	20.2	10.9	28.2	31.9	.48	17.21

(1) CALCULATED USING HIGHER OF "AS RECEIVED" OR "EQUILIBRIUM" MOISTURES

FIGURE 10. *Analytical data for seams in the Coal Creek area showing distribution of partings.*



	INTERVAL THICKNESS (cm)	AS RECEIVED MOISTURE	PROXIMATE ANALSIS (%)					
			EQUILIBRIUM MOISTURE	ASH (1)	VOLATILE (1) MATTER	FIXED (1) CARBON	SULPHUR (1) (%)	CALORIFIC VALUE (1) MJ/kg
	100	30.6	24.3	12.4	29.8	27.2	.45	13.99
	150	29.0	24.7	10.5	30.4	30.1	.50	15.15
	200	23.2	21.7	15.6	30.8	30.4	.72	15.33
	228	25.1	18.9	14.8	32.1	28.0	.72	15.53
	86	25.8	21.9	5.4	33.5	35.5	1.14	18.03
	93	26.1	20.5	10.3	33.3	30.3	.71	15.10
	227	29.6	21.4	9.6	30.8	30.1	.54	15.51
	210	30.4	19.3	8.8	31.9	28.9	.62	15.42
NET COAL	1294							
	230	27.0	21.1	2.6	33.4	37.0	.24	19.43
	200	30.8	20.6	3.8	33.3	32.1	.80	17.84
	180	31.6	21.6	3.4	30.6	34.5	.82	17.59
	110	28.6	21.4	5.4	32.8	33.1	1.22	17.72
NET COAL	720							
	95	31.7	19.5	5.5	30.7	32.2	1.19	17.29
	188	31.4	19.9	7.0	32.2	29.4	1.10	16.59
NET COAL	283							

(1) CALCULATED USING HIGHER OF "AS RECEIVED" OR "EQUILIBRIUM" MOISTURES

FIGURE 11. *Analytical data for seams in the Cliff Creek area showing distribution of partings.*

In the Coal Creek Mine area (Inset, Fig. 7), three seams of mineable thickness are exposed and additional or correlative seams are indicated by coal float in the adjacent valley to the northwest. Dips observed in surface exposures are moderate; however, steeper dips and folding were encountered at depth in the older workings on at least one of these seams (McConnell, 1903). No estimate of coal resources is made because of this structural complexity although a small resource is probably present.

Coal seams are considerably steeper and the topography more rugged in the Cliff Creek area. The rapid rise of the land surface away from the creek suggests that resources amenable to surface mining where these seams are presently exposed are negligible. Correlative or additional seams with less deformation may be present, perhaps in the central part of the Trench farther from the bounding faults; however, their discovery awaits subsurface exploration.

Indian River area

The single coal seam exposed in the Indian River area is thin, high in ash and has been thermally upgraded, possibly by post-depositional intrusions. The predominance of conglomerates and coarse sandstones in exposures observed in the area suggests that associated coal seams are likely to be lenticular and restricted in extent and does not augur well for the presence of significant coal resources.

CONCLUSIONS

Small deposits of lignitic to bituminous rank coal occur within deformed early Tertiary strata along Tintina Trench. Inferred coal resources at any one locality are limited by structural complexity, variable seam thickness and the small lateral extent of coal-bearing strata within the Trench. Much exploration work will be required to delineate mineable deposits, and difficult access to some localities will increase exploration costs.

The probable small size of mineable deposits along Tintina Trench will restrict mining to small-scale operations. They may, however, be sufficient to supply electricity for local use. The Ross River area appears to hold the most promise for early exploitation because of high rank, moderate structural complexity and good access. The Dawson area coals may ultimately prove to have larger resources, but their remote location, lower rank and higher degree of structural complexity will require a relatively large exploration expenditure to ascertain their true potential. Resource potential of Watson Lake area coals is limited by their low rank, structural complexity and extensive surficial cover.

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