An evaluation of coal-bearing strata at Division Mountain (115H/8 east-half, 105E/5 west-half), south-central Yukon

Tammy L. Allen[1]
Yukon Geology Program

Allen, T.L., 2000. An evaluation of coal-bearing strata at Division Mountain (115H/8 east-half, 105E/5 west-half), south-central Yukon. *In:* Yukon Exploration and Geology 1999, D.S. Emond and L.H. Weston (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 177-198.

ABSTRACT

The Division Mountain area is underlain primarily by Jurassic to Cretaceous(?) sedimentary rocks of the Laberge Group and Tantalus Formation. The Laberge Group is divisible into the following informal units: the Richthofen, Nordenskiöld, Conglomerate, and Tanglefoot formations. The Tanglefoot, which comprises a large portion of the exposed strata at Division Mountain, is here subdivided into the lower and upper members. The lower member consists of quartz-rich sandstone, grit, polymicitic conglomerate and laminated siltstone. The upper member is coal-bearing and typified by white grit, sandstone, and carbonaceous shale. The overlying Tantalus Formation is characterized by thick packages of resistant chert pebble conglomerate with intercalated sandstone beds, which form local highlands at Cub, Corduroy, Division, and Vowel mountains.

The strata at Division Mountain are folded into several upright, tight northwest-trending anticlines and synclines with amplitudes of 2 to 7 km. The folded strata are intruded by feldspar-hornblende andesite sills and dykes.

Organic matter identified within coal and siltstone of the Tanglefoot and Tantalus formations consists of Type III and subordinate Type I kerogen, suggesting the material is largely gas-prone. A combination of thermal maturation indicators (vitrinite reflectance and T_{max}) suggests that the coal and related strata are in the early to late stages of thermal diagenesis. Samples of the underlying Richthofen formation contain Type III kerogen matured beyond the oil window. Local folding and thickening of the Tanglefoot and Tantalus strata, as well as local intrusions in the Tanglefoot, may play a key role in the determination of hydrocarbon potential of the Division Mountain area.

RÉSUMÉ

La région du mont Division est principalement sous-tendue par les roches sédimentaires du Groupe de Laberge et de la Formation de Tantalus du Jurassique au Crétacé (?). On peut diviser le Groupe de Laberge selon les unités suivantes (non officielles) ; les formations de Richthofen, de Nordenskiöld, de Conglomerate et de Tanglefoot. La formation de Tanglefoot, qui constitue une partie importante des strates exposées au mont Division, est divisée ici en membres inférieur et supérieur. Le membre inférieur comprend des grès riches en quartz, des grès grossiers, des conglomérats polygéniques et des siltstones laminés. Le membre supérieur est carbonifère et est caractérisé par des grès grossiers blancs, des grès et du shale carbonifères. La Formation de Tantalus sus-jacente est caractérisé par des ensembles épais de conglomérats résistants à cailloux de chert, interstratifiés de lits de grès qui forment les sommets des monts Cub, Corduroy, Division et Vowel.

Au mont Division, les strates sont plissées en une série d'anticlinaux et de synclinaux serrés de direction nord-ouest ayant des amplitudes de 2 à 7 km et sont par endroits pénétrés par des filons couches et des dykes d'andésite à feldspath et à hornblende.

La matière organique qui a été identifiée dans le charbon et les siltstones de la formation de Tanglefoot et dans ceux de la Formation de Tantalus est surtout constituée de kérogène de type III, avec une fraction subordonnée de kérogène de type I ce qui suggère que le matériau a une forte prédisposition au gaz. Une combinaison des indicateurs de maturité thermique (réflectance de la vitrinite et T_{max}) indique que le charbon et les strates associées ont atteint le stade avancé à tardif de la diagénèse thermique. Des échantillons prélevés dans la formation de Richthofen sous-jacente contiennent du kérogène de type III qui présente une maturité qui a dépassé l'intervalle du pétrole. Le plissement local et l'épaississement des strates les Formations de Tanglefoot et de Tantalus ainsi que la présence d'intrusions par endroits dans la Formation de Tanglefoot pourraient jouer un rôle important dans la détermination du potentiel en hydrocarbures de la région du mont Division.

[1]*tammy.allen@gov.yk.ca*

INTRODUCTION

The Division Mountain area, located along the western margin of the Whitehorse Trough (Fig. 1), contains one of the Yukon's most prospective coal desposits and may have natural gas potential. The potential for both coal and natural gas is not yet clear. This study attempts to better define the stratigraphy and sedimentology of the coal resources at Division Mountain and aids in the search for coal and hydrocarbon resources in the Whitehorse Trough.

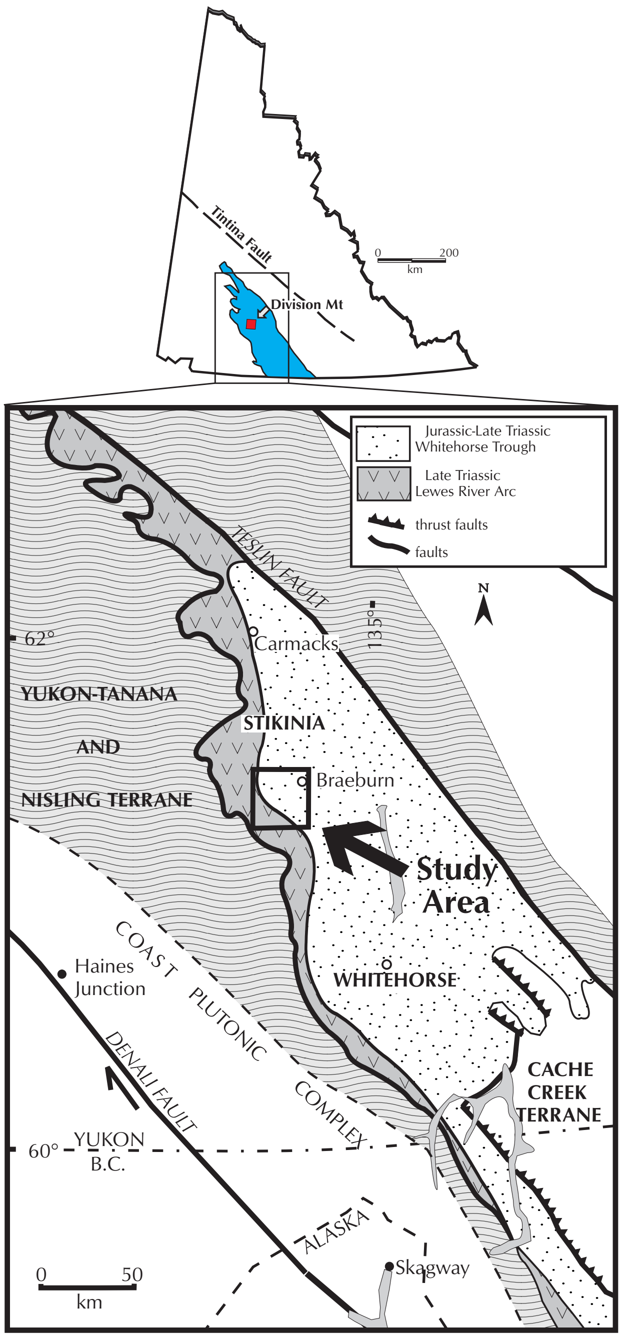

Figure 1. *Location of Division Mountain map area (after Hart, 1997).*

Coal was first discovered near Division Mountain at the turn of the century. Cairnes (1908) identified three coal seams near Teslin Creek and one at the base of Vowel Mountain (Red Ridge). The area then lay dormant until the early 1970s, and has since been intermittently explored. Drilling and trenching has outlined mineable reserves of 52.9 million tonnes of high volatile bituminous B coal (Gish and Carne, 1998). The coal reserves are concentrated in a 50 m interval in the uppermost Jurassic Laberge Group below the Tantalus Formation chert pebble conglomerate (Mineral Resources Branch, 1998). Strata closely related to the coal measures consist of bleached quartzo-feldspathic sandstone, grit, pebbly grit, as well as grey siltstone and carbonaceous shale. North of Division Mountain, in the Carmacks region, coal seams occur in the upper Laberge Group as well as the Tantalus Formation. This study examines the uppermost Laberge Group strata associated with the coal measures in the Division Mountain area, focussing on their lithology, relationships, and distribution.

Little exploration or research has been initiated to determine the hydrocarbon potential of the Whitehorse Trough (Fig. 1), although the Trough is believed to be an immature, mainly gas-prone basin (Gilmore, 1985). Previous research was limited to a reconnaissance study of analysis, including a total of eight samples collected for analysis in the Division Mountain area (Gilmore, 1985; Beaton et al., 1992). No seismic surveys or drilling have been undertaken. In this study, twenty-three samples from the map area were analyzed to test source rock potential.

LOCATION, ACCESS, AND EXPOSURE

The Division Mountain area (parts of Vowel Mountain, 115H/8 east-half and Braeburn Lake, 105E/5 west-half) is located approximately 30 km west of the Braeburn airstrip, off the North Klondike Highway (Fig. 2). The North Klondike Highway crosses the northeast corner of the study area, approximately 90 km north-northwest of Whitehorse. Access from the highway is provided along Klusha Creek by the 4-wheel drive Trans Canada Trail (formerly the Dawson Trail). Further access is provided by an exploration road that branches off the Trans Canada Trail, approximately 21 km from the Braeburn Airstrip and continues due west to the Nordenskiöld River.

Fieldwork was mainly by foot traverse with limited helicopter access provided from Whitehorse. A walking trail (Dalton Trail), paralleling the west side of the Nordenskiöld River, provided limited access where portions of the trail have been maintained near Vowel Mountain. A large portion of the Dalton Trail, which originally ran the extent of the map sheet, is overgrown and covered with deadfall from old forest fires. A forest fire covered large portions of the map area during the mid 1960s. Today, these areas of the map sheet are covered with deadfall and dense secondary growth making traversing difficult.

Bedrock exposure is limited to less than 5%. Most streams and low-lying areas are blanketed with thick glacial material. Best exposures of strata occur at Teslin Creek (the discovery area) in trenches and natural exposures, and at Joe Creek, Red Ridge Canyon, Vowel, Cub, Corduroy, and Division mountains. Exposures tend to be scattered along ridge crests, grassy slopes, and canyons where glacial material has been downcut or eroded. Additional information of the coal-bearing strata was obtained from diamond drill core left on the property by Cash Resources Ltd.

PHYSIOGRAPHY

The study area includes two landforms that reflect underlying geology. Rounded hills with low to moderate relief cover most of the area and reflect the recessive strata of the Laberge Group and lower part of the Tantalus Formation. In contrast, a few larger landforms are underlain by thick conglomerate beds of the upper part of the Tantalus Formation. Elevations range from 700 to 1570 m (at Vowel Mountain). Overall, the ground is heavily vegetated except for south-facing slopes that are typically grass to aspen and poplar covered, providing patchy exposure.

Major watercourses in the map area include the approximately north-south oriented Nordenskiöld River and Klusha Creek (Fig. 2). These watercourses are small compared to the valleys they occupy, as the valleys were sites of large meltwater channels (outwash plains) during the McConnell glacial period (late Pleistocene; Klassen and Morison, 1987; Hughes, 1989). The Nordenskiöld and Klusha valleys are confined on either side by multiple McConnell age glaciofluvial terraces (Hughes, 1989), that extend 1 to 2 km across the valley bottoms, covering potential bedrock exposures. As ice retreated following the last glaciation, glaciofluvial plains were downcut in response to base-level change, leaving behind the stepped terraces that formed the valley walls. Cash Resources Ltd. intersected 60 m of overburden in drill holes along Klusha Creek and Nordenskiöld River terraces (Gish and Carne, 1998).

Braeburn Lake and the surrounding low ground consists of glaciofluvial and/or glaciolacustrine deposits (Klassen and Morison, 1987). Numerous swamps, small ponds and lakes occur within the study area, notably in areas once occupied by glaciers.

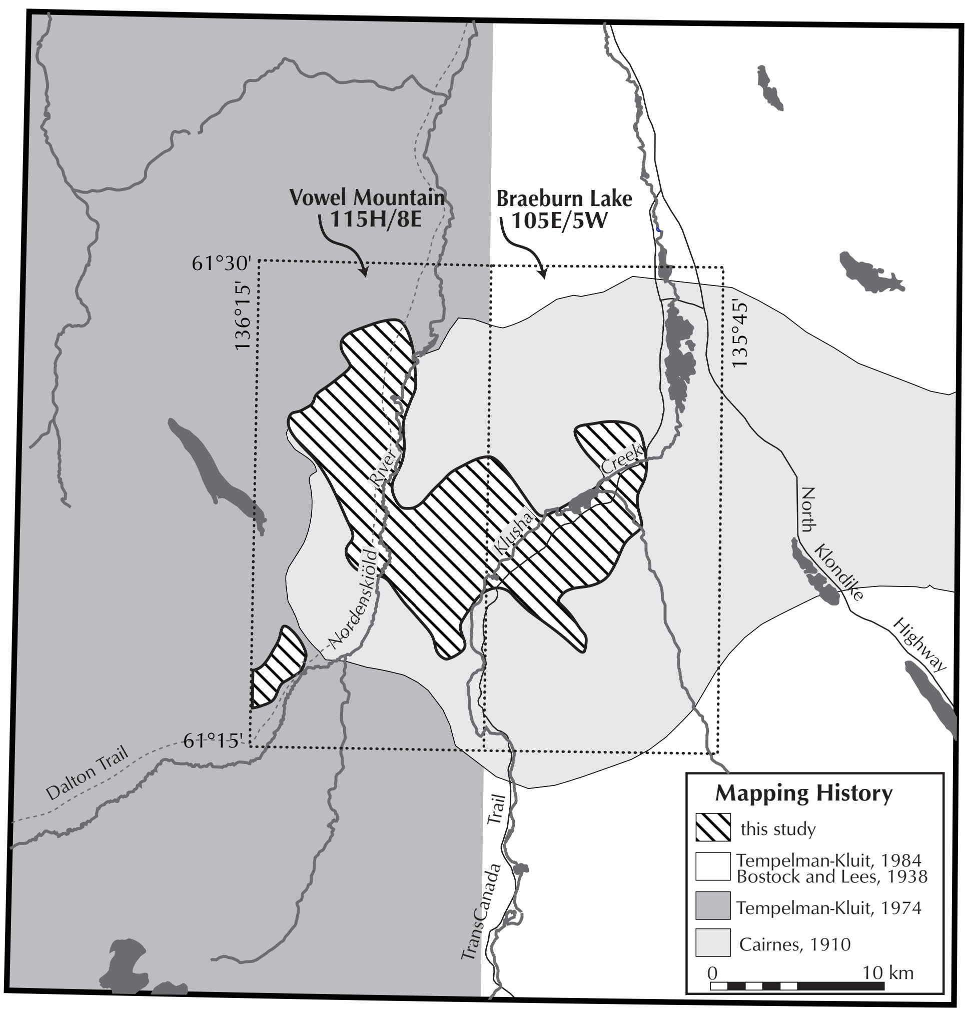

Figure 2. *Limits of previous and recent mapping in the Division Mountain area.*

PREVIOUS WORK

Cairnes (1910) first mapped the Division Mountain area, defining the Nordenskiöld dacites, Laberge series and Tantalus conglomerate. Lees (1934), maintaining Cairnes' nomenclature for sedimentary packages, mapped the Laberge map sheet and proposed the Lewes River Group. Bostock and Lees (1938) named the Nordenskiöld dacite, the Nordenskiöld formation, and the Tantalus conglomerate, the Tantalus Formation. In 1984, Tempelman-Kluit informally subdivided the Laberge Group into the Richthofen, Conglomerate, Nordenskiöld, and Tanglefoot formations on the Laberge map sheet. Refer to Appendix A for a summary of geological mapping in the Division Mountain area.

A geology map by Carne and Gish (1996) included the coal measures in the Tanglefoot formation, while assigning strata directly underlying the coal measures to the Richthofen formation. However, this interpretation is inconsistent with other reports regarding the Whitehorse Trough (Tempelman-Kluit, 1984; Hart, 1997). In this study, the coal measures are included in the upper member of the Tanglefoot formation. The underlying strata are included in the lower member of the Tanglefoot formation.

John Quinn and H.E. Porter first staked coal near Division Mountain in 1903 (Yukon Minfile, 1997). The next record of coal exploration was in 1970. Since then, intermittent exploration has outlined raw coal reserves estimated at 54.7 million tonnes (Burke, 1998). Exploration history is outlined in Appendix B.

Previous studies dealing with hydrocarbon potential in the Division Mountain area include six samples collected from the Cairnes Seam at Teslin Creek that suggested a low hydrocarbon potential (Beaton et al., 1992). In 1985, the Petro-Canada Whitehorse Field Party, as part of a hydrocarbon reconnaissance in the Whitehorse Trough, collected two samples from the map area that also gave poor results (Gilmore, 1985).

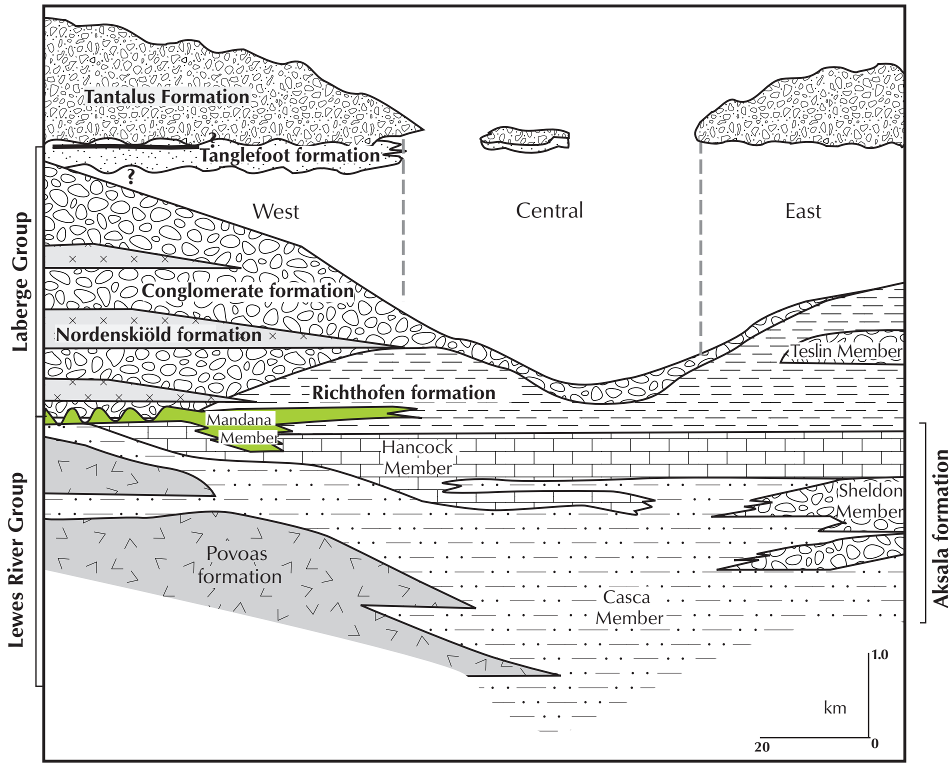

Figure 3. *Stratigraphic representation of the Whitehorse Trough (after Hart, 1997). The contact between the Conglomerate formation and the overlying Tanglefoot formation is undetermined, as is the upper contact of the Tanglefoot formation.*

PRESENT WORK

This project involved bedrock mapping at 1:50 000 scale of coal-bearing and related strata in the Division Mountain area, during the 1999 field season. Samples were collected for palynology and source-rock potential determination (TOC, Rock-Eval, and vitrinite reflectance).

REGIONAL SETTING

LEWES RIVER GROUP

The Upper Triassic Lewes River Group records the earliest known sedimentation in the Whitehorse Trough (Lees, 1934; Wheeler, 1961; Fig. 3). The basal Povoas formation, (Tempelman-Kluit, 1984) comprises largely volcanic rocks, and is dated as Carnian (and older?; Tempelman-Kluit, 1984). The overlying Upper Triassic to Jurassic Aksala formation rests in part, conformably on the Povoas formation (Hart, 1997). Tempelman-Kluit (1984) divided the Aksala formation into the

Casca, Hancock, and Mandanna members, consisting largely of sandstone, siltstone, mudstone, and limestone, deposited within a marine environment (Fig. 3). The upper contact of the Aksala formation (Tempelman-Kluit, 1984) is conformable with the Laberge Group, although locally disconformable (Hart, 1997).

LABERGE GROUP

The Jurassic Laberge Group (Cairnes, 1910) is a thick accumulation of marine conglomerate, tuff, shale, sandstone, and coal. The Laberge Group is conformable (Bostock, 1936; Bostock and Lees, 1938) to unconformable (Cairnes, 1910; Cockfield and Bell, 1926; Lees, 1934) over the Lewes River Group. Tempelman-Kluit (1979) argues that the contact between the Lewes River and Laberge groups is unknown; rather the two groups represent a single continuous sequence of fanglomerate, beach, reef, and turbidite deposits. The Laberge Group has traditionally been subdivided into three units, although mapped as one (Cockfield and Bell, 1926; Bostock and Lees, 1938). Tempelman-Kluit (1984) was the first to informally subdivide and map the Laberge Group as four lithologically different units including Richthofen, Conglomerate, Nordenskiöld, and Tanglefoot formations (Fig. 3).

No complete section has been recorded where the entire thickness of the Laberge Group could be accurately measured (Cairnes, 1910; Bostock and Lees, 1938). The known thickness of the Laberge Group ranges from over 1158 m in the Braeburn-Kynocks area (Cairnes, 1910) to an assumed thickness of 3048 m in the Whitehorse district (Cockfield and Bell, 1926), although this is likely under represented (Hart, 1997).

The Laberge Group succession was initially recorded as Jurassic or Cretaceous (Cairnes, 1910) in the Braeburn area. Later examinations (outlined in Table 1) of the Laberge Group revealed a more constrained age. In the Whitehorse area, a middle Lias to lower Middle Jurassic age was assigned to the Laberge Group (Cockfield and Bell, 1926). In 1934, Lees presented a lower Liassic to lower inferior Oolite age for the Laberge Group in the Laberge area. At Five Finger Rapids, fossils 853 m above the base of the series were dated as late Lower or early Middle Jurassic (Bostock, 1936). Wheeler (1961) reported an age range of lower Lias to early Middle Jurassic for the Laberge Group in the Whitehorse area. Trigoniid bivalves identified from Red Ridge Canyon have been dated as middle Bajocian (Tempelman-Kluit, 1974; Poulton, 1979), suggesting Laberge strata in Red Ridge Canyon is of the lower member of the Tanglefoot formation. Tempelman-Kluit (1984) suggested an age of Hettangian to Bajocian (Early to Middle Jurassic) for the Laberge Group in his map legend. In the Whitehorse area, Palfy and Hart (1998) determined an age of Sinemurian to Bajocian based on ammonite stratigraphy.

TANTALUS FORMATION

The upper Jurassic to early Cretaceous(?) Tantalus Formation (Cairnes, 1910; Cockfield and Bell, 1926; and Lees, 1934; Bostock, 1936) represents the most recent record of deposition in the Whitehorse Trough. The Tantalus Formation, characterized by thick-bedded chert-pebble conglomerate, was named for the sequence containing coal measures of the Tantalus mine, near Carmacks (Cairnes, 1910).

Table 1. *Summary of recorded age dates for the Laberge Group.*

Author (year)	Age	Area	Evidence
Cairnes (1910)	Jurassic to Cretaceous	Braeburn-Kynocks	Trigonia, Dawsoni, Nerinoea, Maudensis, and Rhynchonella orthidoides
Cockfield and Bell (1926)	middle Lias to lower Middle Jurassic	Whitehorse	numerous small ammonoids and pelecypods
Lees (1934)	lower Liassic to lower inferior Oolite (Early to early Middle Jurassic)	Laberge	Mytilus, Modiola, Gervilla, Pinna, Trigonia, Belemnites
Bostock (1936)	late Lower or early Middle Jurassic	Five Finger Rapids	Hildoceratids, Belemnites, Cucullaca
Bostock and Lees (1938)	early Lower Jurassic		same as Lees (1934)
Wheeler (1961)	lower Lias to early Middle Jurassic	Whitehorse	pelecypods and ammonoids (Hildoceraceae)
Tempelman-Kluit (1974)	middle Bajocian	Red Ridge Canyon, Vowel Mountain	Trigoniids (upper Laberge Group)
Tempelman-Kluit (1984)	Hettangian to Bajocian	Laberge	not stated
Pálfy and Hart (1995)	Sinemurian to Bajocian	Whitehorse	ammonite stratigraphy

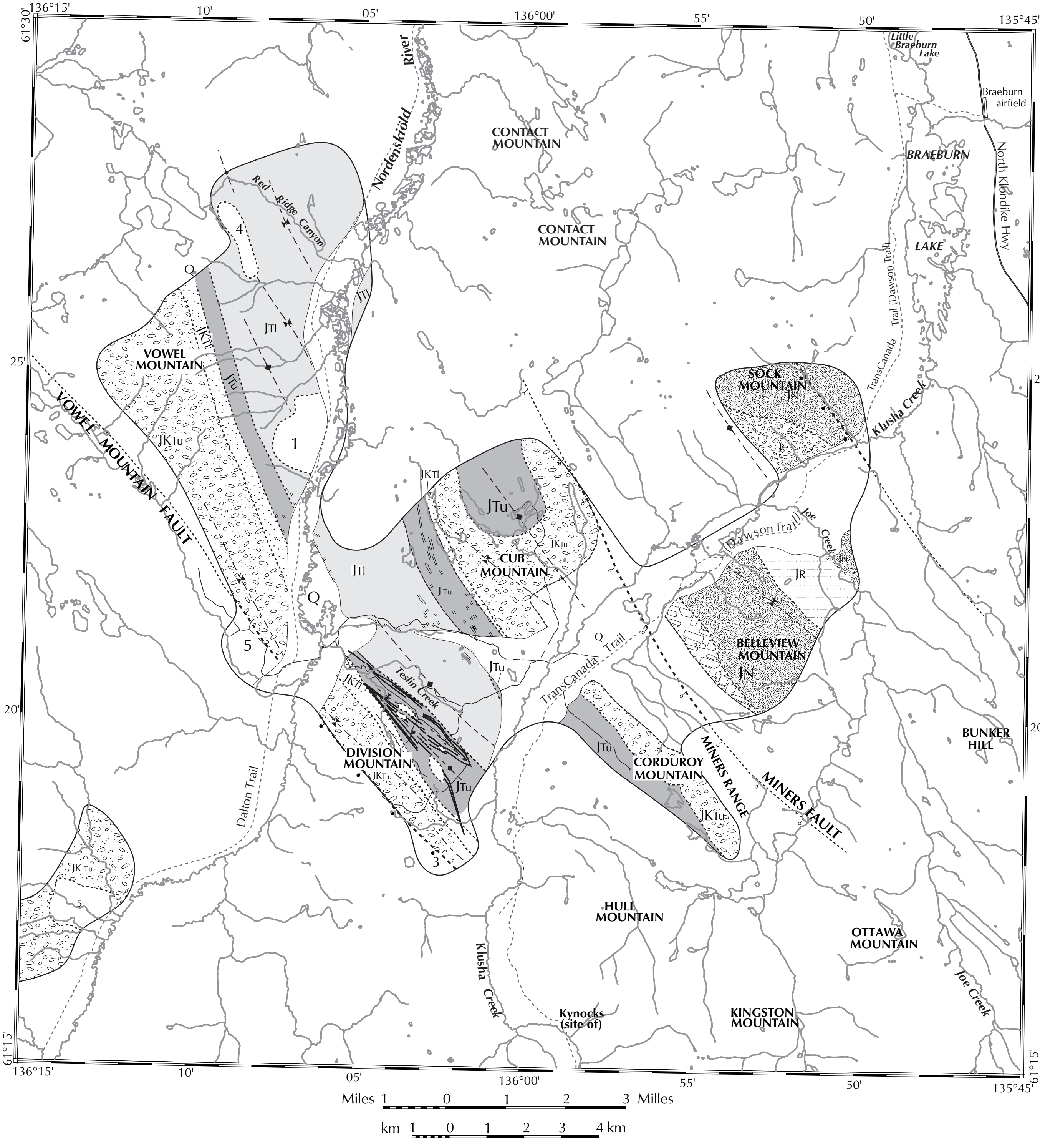

Figure 4. *Geological map of the Division Mountain area (after Allen, in progress). See Figure 1 for location and next page for legend.*

LEGEND

QUATERNARY

Q — unconsolidated sand, silt and gravel

UPPER CRETACEOUS(?)
CARMACKS GROUP(?)

1 — green to light greyish-red feldspar- and hornblende-porphyry sills, dykes, and flows

2 — maroon feldspar porphyry

3 — greyish-red feldspar porphyry and breccia

4 — greenish-black monzodiorite

5 — amygdaloidal to vesicular basalt and extrusive flows

UPPER JURASSIC to LOWER CRETACEOUS
TANTALUS FORMATION

JKTu — Upper Member - Clast-supported chert-pebble conglomerate, resistant and thickly bedded, with intercalated medium- to coarse-grained sandstone beds made up of quartz, feldspar, and chert grains. Clasts are typically 1 to 3 cm across, subrounded to well-rounded and moderately to well sorted.

JKTl — Lower Member - Matrix-supported chert-pebble conglomerate, made up predominantly of coarse- to very coarse-grained sandstone composed of quartz, feldspar, and chert grains.This member is recessive. Also contains subordinate fine-grained, grey to brown weathered, laminated, plant-rich sandstone.

LOWER to MIDDLE JURASSIC
LABERGE GROUP

Tanglefoot formation

JTu — Upper Member - Yellowish grey to bleached white, coarse- to very coarse-grained sandstone, grit, and pebbly grit with conspicuous quartz and feldspar granules within a white to buff chalky cement. Other lithologies include grey interlaminated siltstone and very fine-grained sandstone, carbonaceous shale, and coal seams.

JTl — Lower Member - Light olive grey, fine- to very coarse-grained quartz-rich sandstone, grit, heterolithic conglomerate, and laminated siltstone. Fining-up packages commonly include the above lithologies. Macerated plant debris is common at the top of sequences. The conglomerate is matrix- to clast-supported with clasts ranging from pebbles to boulders, subangular to rounded, and include vein quartz, felsic granite and porphyry.

Nordenskiöld / Conglomerate formations

JC JN — JN - Steel grey to medium greenish grey tuff, weathers dark brown, medium- to coarsely crystalline, well indurated, massive, locally calcareous.

JC - Olive grey, heterolithic conglomerate, clasts range from pebbles to boulders including predominantly granitic rocks up to 30 cm across and subrounded to well-rounded.

Richthofen formation

JR — Fine-grained grey sandstone, weathered buff, parallel- to cross-laminated, dark grey siltstone, recessive, platy to flaggy beds.

SYMBOLS

Geological contact (defined, approximate, assumed)...........................

Fault, displacement unknown (defined, approximate, covered)............................

Fold axis (anticline, syncline).................................

Coal seam..

Limit of mapping..

Roads..

Figure 4. *continued*

LOCAL STRATIGRAPHY

RICHTHOFEN FORMATION

In the Division Mountain area, the Richthofen formation (Tempelman-Kluit, 1984) has only been recognized near Joe Creek (Fig. 4) where siltstone and intercalated sandstone beds are exposed in intervals less than 15 m thick in a few outcrops. The siltstone, medium to dark grey, with thin laminae (1 to 20 mm) of very fine-grained, calcareous sandstone, exhibits platy weathering. These sandstone laminae are light grey and weather buff. Thicker sandstone beds interbedded with the siltstone are commonly 30 cm thick, although may be as thick as 75 cm (Fig. 5). These beds are resistant and have sharp top and basal contacts with the siltstone. The sandstone is parallel- to cross-laminated and locally exhibits soft sediment deformation.

Figure 5. *Interbedded sandstone and siltstone beds of the Richthofen formation, Joe Creek.*

CONTACT RELATIONSHIPS

In the Division Mountain area, contacts with the Richthofen formation were not observed, although it is believed that strata on Joe Creek are within a faulted anticline, with Richthofen formation on the western limb of the fold. Elsewhere in the Whitehorse Trough, the lower contact of the Richthofen is conformable to transitional over limestone of the Hancock Member and locally unconformable on limestone and conglomerate of the Hancock Member (Hart, 1997).

THICKNESS

Due to limited exposure, the thickness of the Richthofen formation in the map area is unknown. In the Whitehorse region, the Richthofen formation ranges from 1500 m thick at Horse Creek to approximately 200 m at the Takhini Game Farm, west of Lake Laberge, showing a dramatic decrease in thickness to the west (Hart, 1997).

AGE

Harpoceratid ammonites (possibly *Protogrammoceras*) were collected by Tempelman-Kluit from strata in Joe Creek (GSC Loc No. C-86549) and dated as late Pliensbachian (identified by H.W. Tipper, unpublished report). The age of strata in the drainage parallel and north of Joe Creek was determined as Lower Jurassic (probably upper Sinemurian), based on the fauna collection GSC Loc No. C-86697. Fossils identified in this collection include pelecypod fragment and *Paltechioceras(?)* sp. (a loosely coiled ammonite; H.W. Tipper, unpublished report).

NORDENSKIÖLD AND CONGLOMERATE FORMATIONS

Age equivalent Nordenskiöld and Conglomerate formations crop out on Belleview Mountain, Sock Mountain (name proposed here for geographic reference) and Joe Creek as fine- to medium-grained tuff and heterolithic conglomerate (Fig. 4).

Nordenskiöld formation

Typically, tuff of the Nordenskiöld formation weathers brownish green on the outer surface with a weathering rind 2 to 20 mm thick, forming a sharp to diffuse boundary around the fresh rock (Fig. 6a). On the fresh surface, the tuff ranges from medium bluish grey to brownish grey and locally greyish red (colour scale: 5 R 4/2). The tuff is massive and breaks into sharp, angular fragments due to intense fracturing. The rocks are well indurated with a siliceous and, locally, a calcareous cement. Locally, the tuff is banded with fine- to coarse-grained bands ranging from grey to greyish red. In one locality, carbonized plant debris was noted.

Overall, the rock is medium- to coarse-textured and moderately to well sorted. Individual grains of predominantly quartz and feldspar are crystalline to subcrystalline; the rock displays no obvious structures. The percentage of feldspar, 1 to 2 mm across, varies from 5 to 20% within a finer matrix of predominantly feldspar and quartz. Small quartz phenocrysts (< 1 mm across), comprising 5 to 15% of the rock, occur as rounded glassy crystals with broken faces. The tuff locally has zones of differential weathering demonstrating colour mottling of light and dark grey in a honeycomb style (Fig. 6b).

A very fine- to fine-grained sandstone, which may be a finer grained version of the tuff, occurs on Joe Creek in association with grey laminated shale and intercalated calcareous sandstone. The sandstone is pale yellowish brown (tawny), fine- to medium-grained and well sorted. It is a well indurated, quartz-rich sandstone with a small percentage of muscovite and plant debris, and rusty patches in the cement. This lithology occurs in the middle of a syncline, suggesting that it is younger than the coarser-grained tuff.

On Belleview and Sock mountains, coarse- to very coarse-grained tuffaceous sandstone (Fig. 6c), closely associated with conglomerate, appears to interfinger the Nordenskiöld dacite. The sandstone is medium olive grey on fresh surfaces, with a salt and pepper appearance made up of almost equal amounts of feldspar and quartz with lesser hornblende. Feldspar occurs as chalky white to buff laths and crystals 1 to 2 mm across. Quartz crystals (< 4 mm across) are white to dark grey, rounded and resistant. The matrix between the crystals is fine grained and blurry, ranging from dark olive grey to buff. Overall, the sandstone is moderately to poorly sorted and locally contains rounded clasts largely of mud chips up to 18 cm across (less than 10%).

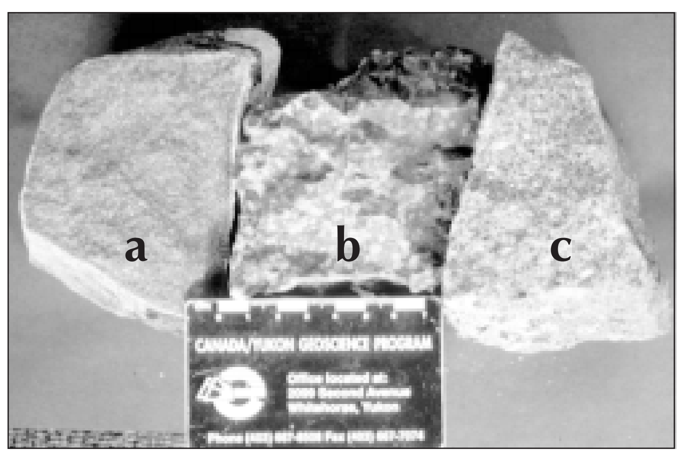

Figure 6. *Tuff of the Nordenskiöld formation: a) medium-textured and medium grey, b) mottled weathering of the grey tuff, c) coarse-grained and olive grey.*

Conglomerate formation

The Nordenskiöld tuff occurs associated with a polymicitic conglomerate assigned to the Conglomerate formation on Sock Mountain, although the relationship is not exposed or well understood. In outcrop, the contact of the polymictic conglomerate with neighbouring tuff and sandstone is sharp. The conglomerate (Fig. 7) is dark brown on the weathered surface, dark olive grey on the fresh surface and locally iron-stained. The poorly sorted conglomerate is clast-supported (80 to 90% clasts) with clasts ranging from small pebbles to boulders up to 30 cm in diameter. Most clasts are subround to round, although they may range from angular to well rounded. Clast boundaries are sharp to diffuse. Due to dense lichen cover, clast lithologies are difficult to differentiate, but include felsic porphyritic, granitoid and very fine-grained maroon rocks. The matrix is fine- to very coarse-grained, consisting primarily of euhedral feldspar and quartz (1-3 mm) with minor biotite (1-2 mm) and dull black rounded grains (2-5 mm).

Figure 7. *Conglomerate on Belleview Mountain. Clasts range from pebbles to boulders up to 30 cm across; lithologies consist predominantly of felsic intrusive clasts.*

CONTACT RELATIONSHIPS

In the Division Mountain area, the Conglomerate formation appears to underlie and interfinger the Nordenskiöld formation, although observations are based on limited exposure. In the Whitehorse area, the Nordenskiöld formation occurs at several levels within a stratigraphic interval including most of the Conglomerate formation and upper Richthofen formation (Hart, 1997). At Braeburn, Takhini Hot Springs, and Fish Lake, the Laberge Conglomerate conformably overlies the Lewes River Group (Dickie and Hein, 1988).

THICKNESS

In the Division Mountain area, the thickness of the Nordenskiöld and Conglomerate formations is undetermined. In the Whitehorse region, the Nordenskiöld ranges from 200 to 700 m at Takhini Crossing, while the Conglomerate formation ranges from 1 to 3 km thick (Hart, 1997).

AGE

No ages were determined for the Nordenskiöld or Conglomerate formations in the Division Mountain area, although the age of the Nordenskiöld is well constrained in the Whitehorse area as early to late Pliensbachian (Palfy and Hart, 1995; Hart, 1997).

TANGLEFOOT FORMATION

The Tanglefoot formation (Tempelman-Kluit, 1984) occurs on the limbs of an anticline (west)–syncline (east) pair between Vowel and Contact mountains (Fig. 4). On the south side of Klusha Creek, the Tanglefoot formation continues in an anticline between Division and Cub mountains. Based on lithostratigraphic differences in the Division Mountain area, the Tanglefoot formation can be subdivided into two mappable units, here named the lower and upper members (Fig. 8).

Lower member

The lower member of the Tanglefoot formation consists of repeated fining-upward sequences on the order of 25 cm to 7.5 m, averaging 1 to 2 m thick (Fig. 8). These successions typically consist of pebbly conglomerate or grit at the base, and fine sandstone or siltstone at the top. Lithologic changes within the successions are gradational, although contacts between successive sequences are generally abrupt and locally undulating with approximately 10 to 20 cm relief.

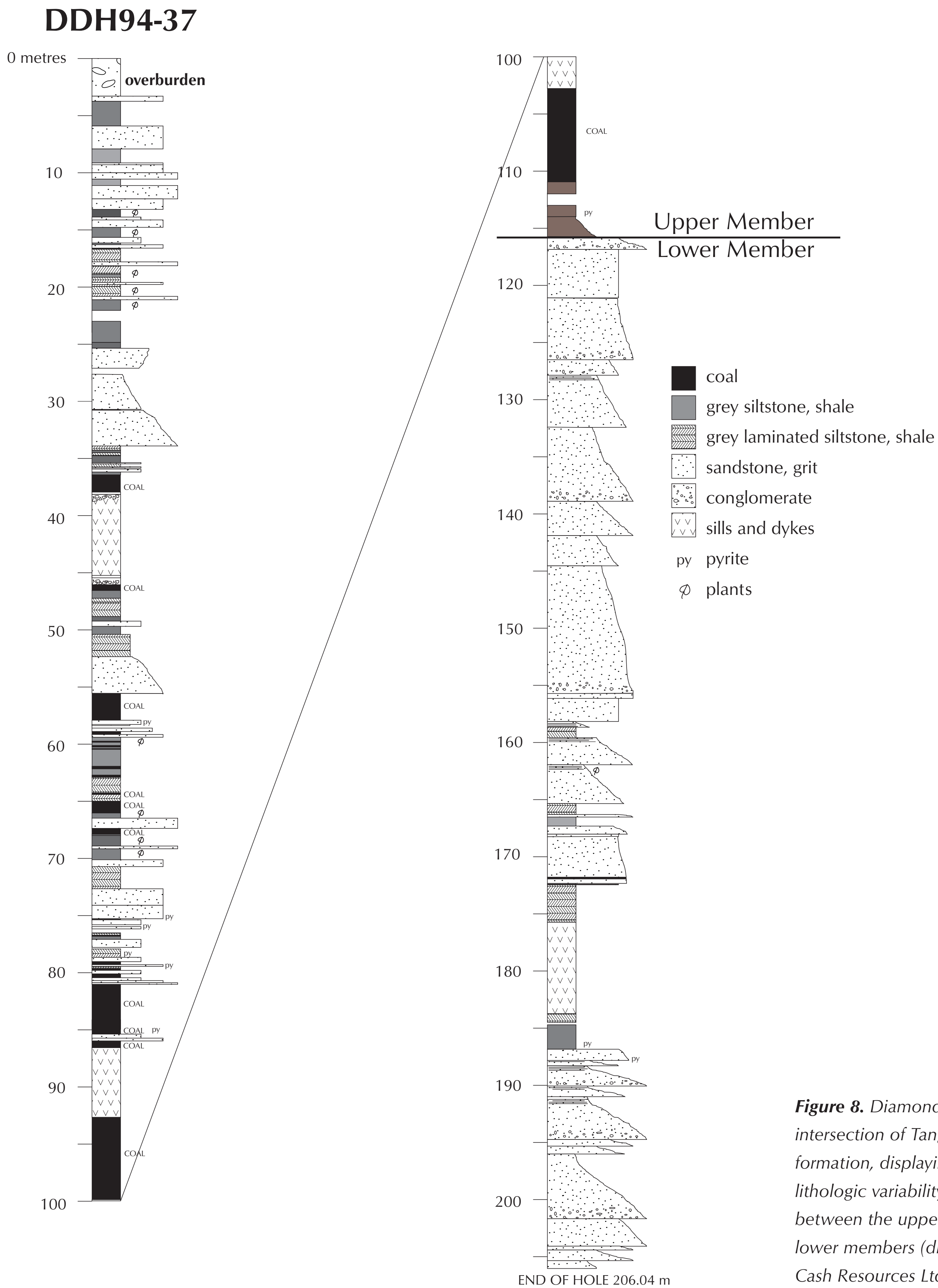

Figure 8. *Diamond drill hole intersection of Tanglefoot formation, displaying lithologic variability between the upper and lower members (drilled by Cash Resources Ltd.).*

The conglomerate is heterolithic with an overall colour of light olive grey to yellowish grey and locally weathers dark brown (Fig. 9). Clasts, ranging from granules up to boulders 30 cm across, including vein quartz, buff to dark grey mudstone, as well as felsic granitic, metamorphic, and volcanic lithologies. Near Red Ridge Canyon, the clasts are generally smaller, ranging between 0.5 and 3 cm. The overall texture of the conglomerate ranges from matrix- to clast-supported with subangular to rounded clasts. The matrix is quartz-rich with lesser amounts of feldspar and minor biotite, similar to the composition of the associated sandstone. The conglomerate is typically very poorly sorted with no obvious imbrication.

Figure 9. *Heterolithic conglomerate of the Tanglefoot formation lower member, Teslin Creek. The conglomerate includes clasts of vein quartz, buff and dark grey mudstone as well as granitic, metamorphic and volcanic lithologies.*

Figure 10. *Cavernous sandstone typical of the Tanglefoot formation lower member, Teslin Creek. A large percentage of the grains are quartz and K-feldspar with lesser amounts of plagioclase feldspar, biotite, and plant debris.*

The sandstone and grit commonly have a cavernous appearance (Fig. 10), notably in exposures at Teslin Creek and Red Ridge Canyon. The sandstone and grit are light olive grey to yellowish grey, friable, and massive to crudely bedded. The sandstone and grit, dominated by quartz grains (50 to 90%), also contains K-feldspar (15 to 20%), and plagioclase feldspar (up to 10%) as well as minor biotite, lithic grains, and carbonaceous plant debris. Finer grained sandstone, at the tops of fining-upward sequences, contains compressed macerated plant debris, subparallel to bedding.

Fine-grained lithologies of the lower member are best exposed at Red Ridge Canyon. The fines consist of laminated olive grey to dark grey siltstone and very fine-grained sandstone. Common sedimentary structures in the fines include starved ripples and parallel- to cross-laminae (1 to 10 cm). Carbonaceous laminae are common and bivalve fossils are locally abundant (Red Ridge Canyon and the east side of Vowel Mountain). Thicker beds, 1 to 25 cm thick, of fine- to medium-grained sandstone are intercalated within the siltstone package, comprising approximately 30% of a section. These sandstone beds are light grey on the fresh surface, weather buff to yellowish grey and are locally iron-stained. They are well indurated with siliceous to calcareous cement and exhibit abrupt bases and planar to rippled abrupt tops. Thin silty bands (4 to 10 mm) are common in these sandstone beds. Coal was not observed in this member.

Upper member

The upper member of the Tanglefoot formation consists of very coarse- to fine-grained sandstone, pebbly grit, siltstone, carbonaceous shale, and coal. The coal seams have previously received extensive study, although little attention has been paid to related strata. Contact relationships with coal seams are difficult to determine as coal is generally removed from drill core and there are no natural exposures. In a road cut on the south side of Cub Mountain, coaly shale is in contact with porphyritic sills and dykes. In a trench along Teslin Creek, carbonaceous root traces are noted in siltstone and sandstone beds directly below an exposed coal seam.

Strata associated with the coal measures are distinctive from other lithologies in the map area, including sandstone, grit, and pebbly conglomerate that are typically bleached white, although locally the matrix is medium to dark grey. On the fresh surface, the grit is light grey. The composition of these lithologies is primarily quartz (60 to 90%) and K-feldspar (10 to 25%) with rare plagioclase. The granules are subangular to round and poorly to well sorted. Within the pebbly grit, grains reach up to 1 cm across and occupy approximately 5% of the rock. The sandstone, medium to light grey on the fresh surface, possesses a white to orange chalky matrix between the grains. A small percentage (1 to 2%) of tiny macerated plant debris (1 to 2 mm) occurs scattered in the sandstone. The grit and sandstone are porous and preferentially

Figure 11. *White grit, ubiquitous of the upper member of the Tanglefoot formation. Grains are subangular to subround, poorly to well sorted, with conspicuous quartz and feldspar grains.*

weathered with conspicuous grains of quartz and feldspar giving the rock a stuccoed appearance (Fig. 11).

Finer grained lithologies, noted mainly in drill core intersections, include carbonaceous silty mudstone and shale, grey laminated siltstone and light to medium grey, fine- to medium-grained sandstone, and coal. The silty mudstone and siltstone, olive grey to dark grey on the fresh surface, is crumbly to platy and parallel-laminated (1 to 5 mm) with sandstone laminae (2 to 10 mm) comprising up to 80% of the rock. Well-preserved plant debris (grasses, twigs, and ferns) are commonly compressed along bedding planes of the carbonaceous shale and laminated siltstone. Intercalated fine-grained sandstone beds are flaggy and 2 to 5 cm thick. Beds are massive to planar parallel to cross-stratified with shallow dips at approximately ten degrees. Fining upward sequences are noted within the upper member, although not as common as in the lower member.

CONTACT RELATIONSHIPS

The basal contact of the Tanglefoot formation in the study area is not exposed. The contact between the upper and lower members, only observed in drill core intersections from the east side of Division Mountain, is abrupt with no evident interstratification. On the east side of Vowel Mountain and the southwest side of Cub Mountain, the Tanglefoot formation underlies the Tantalus Formation, although the contact is locally obscured by andesite dykes and sills, as well as overburden.

Outside of the map area, the Tanglefoot formation has been recognized in the Laberge map area (Tempelman-Kluit, 1984). The Tanglefoot formation was also recognized in the Whitehorse map area at Flat Mountain, where it was deposited unconformably on top of Lewes River Group strata (Hart, 1997). In the Whitehorse area, the Tanglefoot formation is unconformably overlain by nearly flat-lying Carmacks Group volcanic rocks (Hart, 1997).

THICKNESS

In the map area, the Tanglefoot formation is approximately 2000 m thick, although this is likely an over-approximation due to intense folding of the strata. The Tanglefoot formation attains a thickness of 500 m at Flat Mountain (Hart, 1997), although Hart's Tanglefoot formation includes chert clasts, which here are included in the overlying Tantalus Formation.

AGE

The upper member, as outlined in this study, has not previously been assigned an age. Elsewhere, the lower member of the Tanglefoot formation has been dated as Toarcian to Bajocian (Middle Jurassic; Tempelman-Kluit, 1984). Fossils identified (GSC collections C-18178 and C-18179 and 57186) from Red Ridge Canyon, north of Vowel Mountain, revealed an age of middle Bajocian for the lower member in the Division Mountain area (Tempelman-Kluit, 1974; Poulton, 1979).

TANTALUS FORMATION

Within the map area, the Tantalus Formation forms Division, Vowel (Red Ridge), Corduroy and Cub mountains. The Tantalus Formation occurs as a steeply dipping syncline to form Vowel Mountain and, along strike, a moderately dipping syncline to form Division Mountain. Cub Mountain consists of a syncline and anticline pair of Tantalus Formation. At Corduroy Mountain, the Tantalus forms a steeply dipping homocline(?), that dips to the northeast. The east side of Corduroy Mountain is faulted, otherwise it may have formed a syncline, along strike with Cub Mountain. The only other occurrence of Tantalus Formation visited this season was west of the Nordenskiöld River where the dip is moderate to shallow in a northeastly direction.

The Tantalus Formation occurs as thickly bedded (5 to 30 m), massive to low-angle cross-bedded conglomerate with lesser

Figure 12. *Corduroy Mountain, which consists of thickly bedded Tantalus Formation conglomerate.*

sandstone, and shale. Coal seams have been reported in the Tantalus Formation in the Carmacks region (Bostock, 1936) and as muddy coal on Corduroy Mountain (D. Long, pers. comm., 1999). The overall colour of the unit is light grey to yellowish grey except where locally bleached or iron-stained. The conglomerate beds are resistant, forming mountains of vertical to near vertical beds with a ribbed (or corduroy) appearance (Fig. 12). Conglomerate beds are typically moderate to well sorted and crudely bedded. Graded beds, as well as fining and less often coarsening up successions, are common in the conglomerate; these characteristics are marked by changes in clast size and abundance. Matrix-supported conglomerate contains up to 40% chert clasts, averaging 0.5 to 4 cm across.

In the Division Mountain area, there are two mappable units within the Tantalus Formation. The lower unit is a recessive weathering, matrix-supported chert-pebble conglomerate, while the upper is a resistant, clast-supported ‘typical’ chert-pebble conglomerate. Unfortunately, due to its recessive nature, the lower member is exposed only in trenches and intersections in diamond drill core on the east side of Division Mountain. This lower unit contains more sandstone than the overlying clast-dominated portion of the Tantalus Formation. The relationship between the upper and lower members was not observed.

The conglomerate is comprised of moderate to well rounded pebbles of chert, quartz, and a small percentage of quartzite, and felsic porphyry (Fig. 13). Chert clasts are widely variable in colour, including white, black, green, greenish grey, buff, grey, and pink. Grey clasts are generally veined or mottled. Clasts are typically 1 to 5 cm in diameter, although locally range up to 20 cm. The clasts are subround to subangular, with moderate to high sphericity and often egg-shaped. The matrix consists of medium- to very coarse-grained sandstone made up of lithologies similar to the framework clasts, with a siliceous to locally calcareous cement.

Figure 13. *Chert pebble conglomerate, typical of the Tantalus Formation, is clast-supported, with a matrix of medium- to coarse-grained sandstone. Clasts consist of subrounded to well-rounded pebbles of vein quartz, chert and a small percentage of quartzite and felsic porphyritic rocks.*

Discontinuous, interstratified sandstone bands, commonly 5 to 50 cm thick, consist of material similar to the conglomerate matrix. The sandstone is medium- to very coarse-grained, with up to 30% granules and less than 5% entrained small chert pebbles. The sandstone is moderately to well sorted, quartz-rich (40% to 50%) with lesser amounts of feldspar and chert and rare carbonaceous plant debris in a white chalky cement. The overall colour of the sandstone is light grey to light olive grey or buff and locally iron-stained. Grains are subangular to subround and moderately to well sorted. Individual sandstone beds are commonly 0.5 to 20 cm thick and massive to cross-bedded.

Another lithology associated with the chert pebble conglomerate, less common than the previous, is a greyish red to medium greyish brown fine-grained sandstone. The sandstone is quartz-rich, well sorted, and characterized by its fine grain size and abundance of well preserved plant material (ferns and grasses). The thickness of this sandstone is unknown as there were only two occurrences noted, both on the east side of Division Mountain, one in a trench and one in a road cut.

In drill core, carbonaceous mudstone as well as parallel-laminated siltstone occur interbedded with the matrix-supported chert pebble conglomerate.

CONTACT RELATIONSHIP

In the Division Mountain area, the only visible contact between the Laberge Group and the overlying Tantalus Formation is intersected in drill core. The observed contact, from the east side of Division Mountain, is abrupt and marked by the appearance of chert. West of the Nordenskiöld River, the contact with the underlying Tanglefoot formation is not observed.

In the Whitehorse area, the Tantalus Formation conformably overlies the Laberge Group (Cockfield and Bell, 1926; Wheeler, 1961). In the Indian River area, the Tantalus Formation unconformably overlies Palaeozoic (?) metamorphic rocks and is intruded and unconformably overlain by andesitic dykes and sills of the Carmacks Group (Lowey and Hills, 1988).

THICKNESS

In the study area, the Tantalus Formation ranges from 745 m on Corduroy Mountain to 1270 m thick on Vowel Mountain, consisting predominantly of conglomerate (D. Long, pers. comm., 1999). Outside the study area, the Tantalus Formation ranges in thickness from 300 m in the Carmacks area (Lowey and Hills, 1988), to 1525 m exposed near Double Mountain (Whitehorse area; Wheeler, 1961).

AGE

No fossils have been obtained from the Tantalus Formation in the Division Mountain area. The age of the Tantalus Formation in other areas is somewhat unconstrained, ranging from Jurassic to Early Cretaceous. Fossils examined from the Tantalus Mine (Carmacks) suggested that the formation is as young as Lower Cretaceous (Cairnes, 1910). Fossils retrieved from the conglomerate in the Wheaton district suggested the formation is as old as Jurassic (Cairnes, 1916). In the Whitehorse region the age was determined as Upper Jurassic (?) and Lower Cretaceous based on plant fossils documented by Cairnes (1916) from Mount Bush (Wheeler, 1961). A Neocomian (early Lower Cretaceous) age was determined in the Aishihik Lake area based on a collection of plant fossils (Tempelman-Kluit, 1974). Palynomorphs collected from the Indian River area indicated an Early Cretaceous (Albian) age (Lowey, 1984; Lowey and Hills, 1988). Hunt and Hart (1994) concluded that the Tantalus Formation of the Whitehorse coal deposit ranges in age from Late Jurassic to Late Cretaceous, based on palynology results.

CARMACKS GROUP

The Carmacks Group is divisible into five mappable units in the Division Mountain area.

Unit 1 is here emphasized as it is intimately associated with the coal-bearing strata. The remaining four units are considered less important as they do not occur with the coal.

Unit 1 consists of feldspar-hornblende andesitic sills and dykes that intrude coal-bearing and underlying strata along south Cub Mountain, west to Division and Vowel mountains (Fig. 4). A large portion of the outcrop exposed between Cub and Vowel mountains consists of these sills and dykes with few sedimentary rock exposures. Diamond drill hole intersections and road cut exposures indicate sills and dykes preferentially occur along or within coaly intervals. Brecciated contacts are commonly observed between the porphyry and neighbouring strata in drill core. The relationships observed of the porphyritic rocks with the neighbouring strata suggest that the sills and dykes post-date deposition of the Laberge Group.

The andesite is relatively fresh to moderately weathered, ranging from well indurated with sharp mineral boundaries, to crumbly and blocky with crystals weathered out. The andesite ranges from medium greenish grey, to dark brownish grey to light grey depending on the degree of alteration.

Phenocrysts, comprising up to 50% of the rock, include predominantly feldspar with lesser hornblende. Feldspar occurs as stubby to elongate euhedral laths and anhedral blebs, generally 1 to 3 mm, although up to 10 mm across. Hornblende occurs as randomly oriented laths (3 to 5 mm) and generally comprises 5 to 10% of the rock. In drill core, buff to white calcite amygdules (<5%) were noted, averaging 1 to 4 mm across, rarely up to 10 mm, and irregularly shaped. In drill core, the andesite was noted as aphanitic near contacts with neighbouring strata and brecciated over a 10 to 40 cm interval.

Due to poor exposure of sedimentary rocks in the map area, the occurrence of these andesites is a useful tool in mapping as they generally occur with the recessive Tanglefoot formation. The sills and dykes rarely intrude the resistant chert pebble conglomerate of the Tantalus Formation.

Unit 2, noted only on the west side of Belleview Mountain, consists of dark maroon, andesitic feldspar porphyry. Plagioclase (2 to 4 mm) comprises 30 to 40% of the rock and hornblende (1 to 2 mm) less than 5%, within a glassy groundmass.

Unit 3 crops out along the south side of Division Mountain. The common lithology of Unit 3 is greyish red feldspar porphyry with 15 to 20% phenocrysts (< 2 mm) in an glassy groundmass. Some exposures are dominated by fragments up to 4 cm across. The fragments are buff weathered, very fine grained, angular to rounded, with sharp contacts. The matrix weathers preferentially.

Unit 4, exposed southwest of Red Ridge Canyon, includes a dark brown weathering greyish black, medium- to coarsely crystalline monzodiorite.

Unit 5 includes exposures in the canyon south of Vowel Mountain and west of the Nordenskiöld River (Fig. 4). The unit consists of dark grey to dark brown resistant weathering flows characterized by the presence of vesicles and calcite amygdules, that locally contain pyroxene and feldspar phenocrysts (5 x 10 mm), comprising 5-40% of rock.

STRUCTURE

The Laberge Group occurs as several northwest-trending syncline-anticline pairs sandwiched between the more resistant Tantalus Formation that forms local uplands. The folds have wavelengths on the order of 2 to 7 km, although as small as 3 m (Carne and Gish, 1996). Northwest- and northeast-trending normal faults with minor dip-slip displacement crosscut the folds (Carne and Gish, 1996). The folded strata are crosscut and locally overlain by porphyritic andesite sills and dykes.

COAL OCCURRENCES

Coal occurrences in the Division Mountain area occur within the Tanglefoot formation, approximately 210 m to 240 m stratigraphically below the base of the Tantalus Formation (Long, 1986). Natural exposures of coal do not occur within the map area, although muddy coal is visible in a road cut near Division Mountain and in a trench above Teslin Creek. Coal occurrences identified by trenching and drilling in the map area occur on the east side of Division Mountain, at Teslin Creek, Cub Mountain, Vowel Mountain (Red Ridge), and Corduroy Mountain. Coal was also reported at Klusha Creek by Peach (1993).

On the east side of Division Mountain, over 30 seams have been identified within the upper member of the Tanglefoot formation, with the thickest and most continuous accumulations of coal present near the base of the unit (Gish and Carne, 1998). Aggregate coal thickness ranges from approximately 10 m in the discovery area (Teslin Creek), to 32 m, 4 km to the southeast (Gish and Carne, 1998). There are fourteen major coal seams ranging from 1.7 m to 17.3 m thick and numerous subordinate seams ranging from 0.10 m to 1.7 m.

The Cairnes Seam, visible in a trench in the discovery area on the north side of Teslin Creek, is the best documented coal seam at Division Mountain (Phillips, 1973; Beaton et al., 1992; Wengzynowski and Carne, 1993). The Cairnes Seam, 12.5 m thick, has two clay and sand partings measuring 92 cm and 54 cm thick (Carne, 1992) and extends for a minimum of 1500 m along strike (Peach, 1993).

Allen (1975) noted coaly fragments in gopher diggings on the southeast side of Cub Mountain and suggested that the coaly material was part of the Tantalus Formation. A 30-m-hand trench on the south side of Cub Mountain intersected numerous patches of coal float in the Laberge Tanglefoot formation (Gish and Carne, 1998).

Coal was originally documented on the east side of Vowel Mountain (Red Ridge), approximately 245 m stratigraphically below the base of the Tantalus Formation (Kirker, 1971) by Cairnes (1908; Yukon Minfile, 1997, 115H 012). A 60-m-long hand trench on Red Ridge intersected coal fragment horizons 1.2 m, 1.4 m, and 1.8 m thick within the Tanglefoot formation (Wengzynowski and Carne, 1994).

A 360-m-long trench on the west side of Corduroy Mountain, intersecting the upper Tanglefoot formation, exposed 23 m of coal in 25 seams, the thickest being 3 m (Gish and Carne, 1998).

COAL QUALITY

The coal at Division Mountain is ranked as high volatile bituminous B to C (0.60-0.64% R_{omax}; Gish and Carne, 1998; Beaton et al., 1992). Coal seams analyzed from within 13 m of the sills and dykes demonstrate higher reflectance values, ranking as anthracite. Calculated averages for raw coal include 2.42% residual moisture, 28.45% ash content, 25.79% volatile matter, 43.18% fixed carbon, 0.43% sulphur and a calorific value of 5216 cal/g (9328 Btu per lb.; Mineral Resources Branch, 1998).

Maceral compositions identified within the Cairnes Seam (Teslin Creek) include: 54% vitrinite (telocollinite, desmocollinite, and vitrodetrinite); 10% liptinite (sporinite, resinite, lipodetrinite, and cutinite); and 36% inertinite (fusinite and semifusinite; Beaton et al., 1992). Beaton and others (1992) concluded that the maceral composition reflected a plant community with abundant grasses and reeds, perhaps of a low-lying wetland flora.

Macerals identified in silty shale from the Richthofen formation of Joe Creek include vitrinite, inertinite and abundant framboidal pyrite (Stasiuk and Fowler, 1999). Macerals identified in silty shale from the lower member of the Tanglefoot formation at Vowel Mountain include abundant inertinite as well as reworked vitrinite and liptinite (liptodetrinite, cutinite and resinite) (Stasiuk and Fowler, 1999).

Regional correlation

The only other reported economic coal seams of the Laberge Group (0.2 m, 1.2 m, 1.1 m, 1.2 m) were worked underground north of Carmacks between 1900 and 1908 at Five Fingers mine (Cairnes, 1908; Long, 1986). Numerous small occurrences of coal within the Jurassic Laberge Group have been reported in the Whitehorse Trough (Yukon Minfile, 1997). Traditionally, economic coal seams in the Whitehorse Trough have been recognized in the Jura-Cretaceous Tantalus Formation. Tantalus coal seams were previously mined at Tantalus Butte (seam 2.4 m to 6 m) and the Tantalus Coal mine (seams 2.3 m, 2.0 m, 0.9 m) near Carmacks, as well as near Whitehorse at the Whitehorse Coal mine (Yukon Minfile, 1997). The Tantalus coal seams also have very low sulphur and high ash contents.

SOURCE ROCK POTENTIAL

Rock-Eval pyrolysis was used to determine thermal maturation (T_{max}) and hydrocarbon potential (total organic carbon (TOC), hydrogen, oxygen, and production indices) of strata in the Division Mountain area. Results from previous Rock-Eval analysis of the Cairnes Seam suggested that the coal has a low petroleum potential (Beaton et al., 1992). One other study of hydrocarbon potential involved reconnaissance sampling of strata in the Whitehorse Trough by the Petro-Canada Whitehorse Field Party (Gilmore, 1985). Analyses of the two samples from the Division Mountain area, indicated some gas potential, but little for oil.

Samples collected for this study were analyzed on a Rock-Eval 6.0 pyrolysis system with results displayed in Table 2.

Total organic carbon contents determined for non-coaly samples ranged from 0.34 to 3.48 wt%, although averaged between 1.2 and 2.2 wt%. Coal and carbonaceous shale total organic carbon ranged from 6.66 wt% for the shale to 63.41 wt% for the coal. Typically, the cut off percentile for source rock potential, in respect to total organic carbon content is 0.5 wt% (refer to Table 3), suggesting that the TOC values represent fair to very good generative source rock potential.

The type of organic matter within the coals and related strata was determined by plotting the following Rock-Eval pyrolysis products: the hydrogen index versus the oxygen index (Fig. 14). Samples with no obvious coaly material plotted along the Type III kerogen evolutionary pathway. This suggests the organic matter in the shale and siltstone is terrestrially derived. Type III kerogen yields low hydrocarbon amounts in the form of oil, and are more likely to generate gas. Coal and carbonaceous shale samples plotted along the Type I and III evolutionary paths (oil- to gas-prone). Type I kerogen is typically oil-prone.

The petroleum potential or genetic index, calculated from Rock-Eval pyrolysis data (S1+S2), suggests that the non-coaly samples analyzed are not oil source rocks (Table 3). The genetic index

Table 2. *Summary of total organic carbon content (TOC), Rock-Eval pyrolysis, and vitrinite reflectance results for the Division Mountain area (from Stasiuk and Fowler, 1999).*

Sample	TOC[1]	S1[2]	S2[3]	S3[4]	S1+S2	PI[5]	HI[6]	OI[7]	RoR%[8]	T_{max}[9]	Lithology	Unit	Easting[10]	Northing
99TLA033	2.27	0.00	0.76	3.19	0.76	0.00	34	141	0.50	430	dark grey mudstone, blocky-crumbly	Tanglefoot fm.	443125	6800880
99TLA044	2.32	0.01	1.31	1.56	1.32	0.01	58	67	0.80	438	dark grey silty shale, carbonaceous	Tanglefoot fm.	442128	6801623
99TLA077	1.83	0.13	0.66	1.15	0.79	0.16	37	63	1.54	475	dark grey silty shale, laminated	Richthofen fm.	454862	6804369
99TLA078	0.79	0.03	0.17	0.38	0.20	0.17	22	48	1.36	482	dark grey silty shale, laminated	Richthofen fm.	454862	6804369
99TLA082	1.67	0.04	0.40	2.45	0.44	0.10	25	147	1.57	484	olive grey silty mudstone	Richthofen fm.	455062	6803958
99TLA112	1.10	0.00	0.03	1.73	0.03	0.00	3	157	1.93	578	medium grey silty shale, laminated	Tanglefoot fm.	440130	6809100
99TLA121	3.48	0.00	1.57	0.73	1.57	0.00	46	21	0.54	438	medium grey silty shale	Tanglefoot fm.	438160	6814310
99TLA122	1.48	0.01	0.35	0.52	0.36	0.02	24	35	0.57	441	olive grey silty shale, laminated	Tanglefoot fm.	438160	6814310
DDH97-63A	1.34	0.00	0.43	0.28	0.43	0.00	32	21	0.60	432	medium grey silty mudstone	Tantalus fm.	445250	6796830
DDH97-63B	0.81	0.00	0.66	0.33	0.66	0.00	81	41	0.66	431	medium grey shaly mudstone	Tanglefoot fm.	445250	6796830
DDH94-37B	2.76	0.21	0.33	0.25	0.54	0.38	12	9	2.01	333	medium grey siltstone, laminated	Tanglefoot fm.	444240	6798550
DDH95-52A	1.09	0.00	0.96	0.29	0.96	0.00	89	27	0.65	432	medium grey siltstone	Tantalus fm.	444720	6797525
99TLA023	63.41	0.00	10.44	31.34	10.44	0.00	17	49	0.54	432	coal	Tanglefoot fm.	443630	6798855
99TLA024	47.79	0.00	7.72	25.93	7.72	0.00	16	54	0.53	432	coal	Tanglefoot fm.	443663	6798884
99TLA031	58.20	0.13	33.50	34.97	33.63	0.00	59	60	0.55	430	coal	Tanglefoot fm.	444158	6799525
99TLA042	46.75	0.00	16.05	46.81	16.05	0.00	35	100	0.45	438	coal	Tanglefoot fm.	442234	6801702
99TLA043	55.02	0.00	34.55	36.28	34.55	0.00	64	66	0.53	433	coal	Tanglefoot fm.	442234	6801702
99TLA051	57.46	0.00	23.38	40.59	23.38	0.00	41	71	0.49	428	coal	Tanglefoot fm.	441841	6801742
99TLA053	6.66	0.07	12.27	13.26	12.34	0.01	189	199	0.56	438	carbonaceous shale	Tanglefoot fm.	441550	6801678
DDH94-37A									2.82		carbonaceous shale	Tanglefoot fm.	444240	6798550
DDH97-63C	57.94	0.00	97.28	3.34	97.28	0.00	169	6	0.59	425	coal	Tanglefoot fm.	445250	6796830
DDH97-63D	52.89	0.13	181.18	2.39	181.31	0.00	344	5	0.63	430	coal	Tanglefoot fm.	445250	6796830
DDH97-63E	19.57	0.04	43.95	2.46	43.99	0.00	226	13	0.65	430	coal	Tanglefoot fm.	445250	6796830
DDH95-52B	61.32	0.14	50.56	4.54	50.70	0.00	84	7	0.68	432	coal	Tanglefoot fm.	444720	6797525

[1]wt % of total organic carbon
[2]mg hydrocarbons/g rock
[3]mg hydrocarbons/g rock
[4]mg CO_2 /g rock
[5](S1/S1+S2)
[6]Hydrogen Index (S2/TOC x 100)
[7]Oxygen Index (S3/TOC x 100)
[8]per cent random reflectance in oil
[9]T_{max} - °C
[10]North American Datum 1983, Zone 8

should be above 2 kg HC/t of rock to qualify as a oil-source rock (Tissot and Welte, 1984). All of the coal and carbonaceous shale genetic indices were above 2 kg HC/t of rock, suggesting that if all parameters are met, they could be viable source rocks for oil.

Four samples analyzed in this study showed high hydrogen indices (two above 200 mg HC/t rock) and contain abundant liptinite. Hunt (1991) suggests that as the liptinite content of organic matter increases so does the hydrogen content and potential for oil generation. Samples with hydrogen index values above 200 are generally considered capable of generating some liquid hydrocarbon (Hunt, 1991).

THERMAL MATURITY

The thermal maturity of the coals and neighbouring strata has been determined with the use of vitrinite reflectance and Rock-Eval pyrolysis.

Vitrinite reflectance is useful for defining zones of potential hydrocarbon generation and provides information on maturation within a basin. Maximum reflectance values of six samples of the Cairnes Seam previously analyzed by Beaton et al. (1992) range from 0.60 to 0.62% R_{omax}. Random reflectance measurements obtained for samples collected in this study range from 0.45 to 2.82% $R_{orandom}$ (Table 2). The highest values obtained are in close proximity of porphyritic to aphanitic sills or dykes. The values between 0.5 and 1.3% $R_{orandom}$ are within the oil window while values between 1.3 and 2.0% $R_{orandom}$ are in the gas window. Samples overmature in terms of source rocks (above 2.0%) are in close proximity of sills and dykes.

T_{max}, a value obtained during Rock-Eval pyrolysis, is an indicator of thermal maturity, assuming that as maturity increases, T_{max} increases. The T_{max} value is partially dependent on the type of organic matter present in the sample, and thus, should be confirmed with additional techniques such as vitrinite reflectance or thermal alteration indices. T_{max} values obtained by Beaton and others (1992) for six samples of the Cairnes Seam ranged from 443-448°C. T_{max} values obtained for samples in this study range from 333° to 484°C. The 333°C value is anomalous and when removed T_{max} ranges from 425° to 484°C. The highest T_{max} values (475° to 484°C) correspond to strata on Joe Creek (underlying the Nordenskiöld strata), and are beyond the oil window in terms of thermal maturation, although within the gas zone. The remaining T_{max} values, 425° to 432°C, indicated that the strata are just below the beginning of the oil window, which is typically 435° to 470°C depending on the type of organic matter present (Peters, 1986).

Table 3. *Rock-Eval interpretative guidelines (modified from Peters, 1986).*

Source rock generative potential			
Quality	TOC (wt%)	S1 (mg HC/g rock)	S2 (mg HC/g rock)
poor	0-0.5	0-0.5	0-2.5
fair	0.5-1.0	0.5-1.0	2.5-5.0
good	1-2	1-2	5-10
very good	>2	>2	>10
Type of hydrocarbon generated			
Type	HI (mg HC/g TOC)	S2/S3*	
gas	0-150	0-3	
gas and oil	150-300	3-5	
oil	>300	>5	
		*assumes Ro = 0.6%	
Level of thermal maturation			
Maturation	PI (S1/S1+S2)	Tmax (ºC)	Ro (%)
top oil window	~0.1	430-445*	~0.5
bottom oil window	~0.4	~465	~1.3
		*varies with type of organic matter	

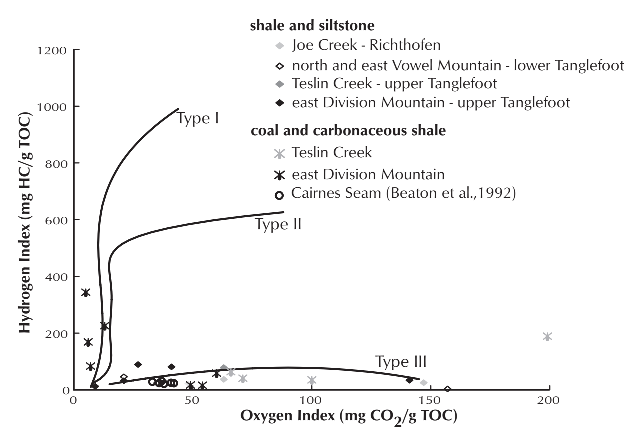

Figure 14. *Hydrogen versus oxygen index cross plot of samples analyzed from the Division Mountain area. Note that a majority of the samples plot around the Type III evolutionary path, suggesting that the organic matter within the strata at Division Mountain is largely derived from terrestrial plants, thus gas prone. A few samples plot along the Type I pathway, suggesting that these samples are more likely oil prone.*

DISCUSSION OF SEDIMENTARY ENVIRONMENT

Several interpretations have been presented for the depositional environment of the Tanglefoot formation including a shallow marine (lower member) to a complex fluvial-deltaic (upper member) environment (Carne and Gish, 1996). Long (1986) suggested that the upper member was deposited on a broad coastal plain where extensive coals accumulated within strandline and high constructive elongate delta deposits. Hart (1997) proposed that the Tanglefoot formation may represent a transition from dominantly fine-grained marine sediments to dominantly coarse-clastic terrigenous sediments, reflecting a dramatic change in the depositional environment from near-shore marine to deltaic or gravely shoreface.

Strata of the Tanglefoot formation is indicative of a shoaling up from shallow marine to a possible non-marine environment. The transition from the lower member to the overlying upper member of the Tanglefoot formation indicates an overall fining upward (Fig. 8). The lower member is much coarser grained and of a different composition than the upper member. The lower member sandstone and conglomerate are quartz-rich with ubiquitous biotite scattered throughout. The conglomerate contains clasts of vein quartz, as well as granitic and lesser volcanic clasts. The granitic clasts in the conglomerate may be indicative of the source for biotite and other minerals in the sandstone and grit. The lower member locally contains marine fossils including Trigoniids and corals. Repeated fining-upward sequences, coupled with the presence of marine fossils in the lower member, suggest deposition in a marine environment. A section at Red Ridge Canyon, over 300 m thick, displays progressive coarsening upward of the lower member that is characteristic of a deltaic environment.

The overlying upper member sandstone contains no obvious biotite and consists largely of quartz and feldspar, suggesting a change in source for the sediments. Faunal records are absent in the upper member, thus there is no direct evidence for a marine versus non-marine argument for these deposits. The presence of thick coal seams in the upper member suggests a periodically stagnant environment with very little sediment influx. Coals typically originate in swamps on low-lying delta plains, alluvial plains, or coastal areas (McCabe, 1984). Vitrinite varieties of the upper Tanglefoot coal seams imply that the coal may have originated in an environment with a significant proportion of grasses and reeds of a low-lying wetland flora (Beaton et al., 1992). Very low sulphur content of the coal suggests the environment of deposition was unaffected by marine waters. Therefore, the upper member was not likely formed in a coastal zone. The presence of abundant laminated fines, and coal seams with intercalated fining upward sequences, suggests that deposition occurred in an alluvial-dominated setting.

Finally, the influx of chert pebbles and cobbles of the Tantalus Formation over the Laberge Group suggests a dramatic change in source. The upper portion of the Whitehorse Trough (Upper Jurassic to Lower Cretaceous) is apparently derived from the northeast, but contains mostly chert clasts for which a northeastern source is unknown (Tempelman-Kluit, 1979), other than the Cache Creek Terrane (Hart, 1997), which is to the south.

The system that deposited Tantalus Formation sediments was much more active than the systems that deposited underlying strata, as indicated by the coarseness of material preserved. Several interpretations have been presented for the origin of the Tantalus Formation, including a continental fluvial origin (Tempelman-Kluit, 1974; Hughes and Long, 1980), braided river or alluvial fan (Bremner, 1988), a fan delta that prograded into a paralic environment (Lowey and Hills, 1988), and a fluvial to marine shoreface transition (Hart and Pelletier, 1989). The uncommon presence of dinoflagellates within lower Tantalus strata attests to the fact that sediments were deposited, at least in part, in a marine environment (Lowey, 1984; Lowey and Hills, 1988; Hunt and Hart, 1994).

In the Whitehorse Trough, economic coal seams of the Tantalus Formation have very low sulphur contents. Low sulphur contents, coupled with an absence of marine fossils, suggest a predominantly non-marine depositional setting for the Tantalus Formation.

CONCLUSIONS

Two members have been recognized within the Tanglefoot formation in the Division Mountain area. The underlying lower member is characterized by quartz-rich sandstone with minor biotite, heterolithic conglomerate, and intercalated laminated siltstone. The upper member is characterized by bleached quartzofeldspathic sandstone and grit with interbedded carbonaceous shale and coal seams.

Traditionally, the Tantalus Formation has been recognized as containing coal seams, but not the older, underlying Tanglefoot formation. The coal seams in the Division Mountain area occur within the Laberge Group Tanglefoot formation. The Tantalus Formation, forming resistant highlands, may be very useful in determining where recessive coal-bearing strata of the underlying Tanglefoot formation occur.

The source rock evaluation completed in this study indicates that there is potential for gas, and perhaps modest amounts of oil source rocks in the upper Laberge Group. Thermal maturity indicators (T_{max} and vitrinite reflectance) suggest that the strata lie at the beginning of the oil window and thus are slightly immature to produce hydrocarbons. Assuming the proper parameters are met, the upper Laberge Group could prove a viable gas, and maybe, oil source.

ACKNOWLEDGEMENTS

I would like to thank Leyla Weston and Panya Lipovsky for their assistance, knowledge and for enduring the "tanglewood" in the field. Thanks are extended to Cash Resources Ltd. for use of their Division Mountain field camp, access to drill core, and company reports. Craig Hart and Frank Gish are acknowledged for helpful discussions. The manuscript was improved by comments from Grant Abbott and Leyla Weston. Safe and reliable helicopter support was provided by Trans North Helicopters out of Whitehorse. Vern Stasiuk and Martin Fowler of the Geological Survey of Canada processed the samples for vitrinite reflectance and source-rock geochemistry.

REFERENCES

Allen, G.E., 1975. Yukon Coal Exploration Licence No. 35. Prospecting Report. Unpublished assessment report #061356, Allen Resource Consultants Ltd., 3 p.

Allen, T.L., (in progress). Preliminary geological map of Division Mountain area (parts of 105E/5 west-half and 115H/8 east-half). Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open File, 1:50 000 scale.

Beaton, A.P., Cameron, A.R. and Goodarzi, F., 1992. Petrography, geochemistry and utilization potential of the Division Mountain coal occurrence, Yukon Territory. Geological Survey of Canada, Paper 92-1E, p. 23-32.

Bostock, H.S., 1936. Carmacks District, Yukon. Geological Survey of Canada, Memoir 189, p. 21-29, 58-64.

Bostock, H.S. and Lees, E.J., 1938. Laberge map-area, Yukon. Geological Survey of Canada, Memoir 217, p. 6-17.

Bremner, T., 1988. Geology of the Whitehorse Coal Deposit. *In*: Yukon Geology, Volume 2, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 1-7.

Burke, M., 1998. Yukon mining and exploration overview – 1997. *In*: Yukon Exploration and Geology 1997, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 3-38.

Burke, M., 1999. Yukon mining and exploration overview – 1998. *In*: Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 2-30.

Cairnes, D.D., 1908. Summary Report. *In*: Geological Survey of Canada, Memoir, 284, H.S. Bostock (ed.), p. 278-280.

Cairnes, D.D., 1910. Lewes and Nordenskiöld Rivers Coal District, Yukon Territory. Geological Survey of Canada, Memoir 5, 63 p.

Cairnes, D.D., 1916. Geological Survey of Canada, Summary Report 1915, p. 40-41.

Carne, R.C., 1992. Summary report on the Division Mountain coal project, southern Yukon for W4 Joint Venture on Coal Exploration Licences Y434 and Y435, Latitude 61°20'N; Longitude 136°08'W NTS, 115H/8. Company report, Archer Cathro and Associates (1981) Ltd., 16 p.

Carne, R.C. and Gish, R.F., 1996. Geology of the Division Mountain coal deposit of Cash Resources Ltd. *In*: Yukon Exploration and Geology, 1995, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 37-42.

Cockfield, W.E. and Bell, A.H., 1926. Whitehorse District, Yukon. Geological Survey of Canada, Memoir 150, 63 p.

Cockfield, W.E., Lees, E.J. and Bostock, H.S., 1936. Laberge sheet, Yukon Territory. Geological Survey of Canada "A" series map 372A, 1:253 440 scale (accompanies GSC Memoir 217).

Craig, D.B. and Laporte, P., 1972. Mineral Industry Report 1969 and 1970, Volume 1, Yukon Territory and southwestern sector District of Mackenzie. Geology Section, Yukon, Indian and Northern Affairs Canada, 188 p.

Dickie, J.R. and Hein, F.J., 1988. Facies and depositional setting of Laberge conglomerates (Jurassic), Whitehorse Trough. *In*: Yukon Geology, Vol. 2. J.G. Abbott (ed.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 26-32.

Gilmore, R.G., 1985. Whitehorse Field Party - September 1985, PetroCanada (National Energy Board Frontier Released Report # 9137-P28-1E, Part 1 of 2).

Gish, R.F. and Carne, R.C., 1998. 1997 final report, Division Mountain project southern Yukon Territory. Unpublished report, Cash Resources Ltd., 21 p.

Hart, C.J.R., 1997. A transect across northern Stikinia: Geology of the northern Whitehorse map area, southern Yukon Territory (105D/13-16). Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Bulletin 8, 112 p.

Hart, C.J.R. and Pelletier, K.S., 1989. Geology of the Whitehorse (105D/11) map area. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open File 1989-2, 51 p.

Hughes, O.L., 1989. Surficial geology, Long Lake, Yukon Territory. Geological Survey of Canada, Map 20-1987, 1:100 000 scale.

Hughes, O.L. and Long, D.G.F., 1980. Geology and coal resource potential of early Tertiary strata along Tintina Trench, Yukon Territory. Geological Survey of Canada, Paper, 79-32, 21 p.

Hunt, J.A., 1994. Yukon coal inventory. Prepared for Energy and Mines Branch, Economic Development, Yukon Territorial Government, 168 p.

Hunt, J.A. and Hart, C.J.R., 1994. Thermal maturation and hydrocarbon source rock potential of Tantalus Formation coals in the Whitehorse area, Yukon Territory. *In*: Yukon Exploration and Geology, 1993, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 67-77.

Hunt, J.M., 1991. Generation of gas and oil from coal and other terrestrial organic matter. Organic Geochemistry, vol. 17, no. 6, p. 673-680.

Kirker, R.J., 1971. Preliminary geological report, Nordenskiold coal area, Yukon Territory. Territorial Coal Exploration Licences #10, #11, and #12, 17 p.

Klassen, R.W. and Morison, S.R., 1987. Surficial geology, Laberge, Yukon Territory. Geological Survey of Canada 8-1985, 1:250 000 scale.

Lees, E.J., 1934. Geology of the Laberge area, Yukon. Transactions of the Royal Canadian Institute, no. 43, vol. 20, Part 1, 48 p.

Long, D.G.F., 1986. Coal in Yukon. *In:* Mineral Deposits of Northern Cordillera. J.D. Morin (ed.), Canadian Institute of Mining and Metallurgy, Special Paper 37, p. 311-318.

Lowey, G.W., 1984. The stratigraphy and sedimentology of siliciclastic rocks, west-central Yukon, and their tectonic implications. Unpublished PhD thesis, University of Calgary, Alberta, 620 p.

Lowey, G.W. and Hills, L.V., 1988. Lithofacies, petrography and environments of deposition, Tantalus Formation (Lower Cretaceous) Indian River area, west-central Yukon. Bulletin of Canadian Petroleum Geology, vol. 36, no. 3, p. 296-310.

McCabe, P.J., 1984. Depositional environments of coal and coal-bearing strata. Special Publication of International Association of Sedimentologists, vol. 7, p. 13-42.

Mineral Resources Branch, 1998. Yukon mineral property update, Economic Development, Yukon Government, 54 p.

Pálfy, J. and Hart, C.J.R., 1995. Biostratigraphy of the Lower to Middle Jurassic Laberge Group, Whitehorse map area (105D), southern Yukon. *In*: Yukon Exploration and Geology 1994. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 73-86.

Peach, A., 1993. An exploration proposal for the Division Mountain Coal Project C.L. Y-434, Y-435, Y-441, Y-442, Whitehorse Mining District, Yukon. Prepared for Cash Resources Ltd. by Allister Peach Geo-Consulting Limited.

Peters, K.E., 1986. Guidelines for evaluating petroleum source rock using programmed pyrolysis. American Association of Petroleum Geologists Bulletin, vol. 70, p. 318-329.

Phillips, M.P., 1973. Report on 1972 Diamond Drilling and Trenching program, Nordenskiöld coal area, Yukon. Prepared for Arjay Kirker Resources Ltd., 10 p.

Poutlon, T.P., 1979. Jurassic Trigoniid bivalves from Canada and western United States of America. Geological Survey of Canada, Bulletin 282.

Stasiuk, L.D. and Fowler, M.G., 1999. Rock-Eval and vitrinite reflectance analysis of coal and shale samples from Yukon, Canada. Prepared for Tammy Allen, Yukon Geology Program, 3 p.

Tempelman-Kluit, D.J., 1974. Reconnaissance geology of Aishihik Lake, Snag and part of Stewart River Map-Areas, West-Central Yukon. Geological Survey of Canada, Paper, 73-41 and map 17-1973, 1:250 000 scale.

Tempelman-Kluit, D.J., 1979. Transported cataclasite, ophiolite and granodiorite in Yukon: Evidence of arc-continent collision. Geological Survey of Canada, Paper 79-14, 27 p.

Tempelman-Kluit, D.J., 1984. Geology, Laberge (105E) and Carmacks (115I), Yukon Territory. Geological Survey of Canada, Open File 1101, two 1:250 000 scale maps.

Tissot, B.P. and Welte, D.H., 1984. Petroleum Formation and Occurrence. Springer-Verlag, Berlin, 699 p.

Wengzynowski, W.A. and Carne, R.C., 1993. Summary report on the Division Mountain coal property, southern Yukon. Prepared for Cash Resources Ltd., 10 p.

Wengzynowski, W.A. and Carne, R.C., 1994. 1993 final report on the Division Mountain coal property, southern Yukon. Prepared for Cash Resources Ltd., 22 p.

Wheeler, J.O., 1961. Whitehorse map area, Yukon Territory. Geological Survey of Canada, Memoir 312, p. 71-74.

Yukon Minfile, 1997. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada. Also available from Hyperborean Productions, Whitehorse, Yukon.

APPENDICES

Appendix A. *Summary of geological mapping in the Division Mountain area (refer to Figure 2 for limits of previous maps).*

Author (year)	Scale	Map
Cairnes (1910)	1:126 720 (2 miles:1 inch)	Braeburn-Kynocks coal area; Cairnes located coal seams on Teslin Creek and base of Vowel Mountain (Red Ridge).
Lees (1934)	1:253 440 (4 miles:1 inch)	Geology of the Laberge area.
Cockfield et al. (1936)	1:253 440 (4 miles:1 inch)	Geology of Laberge map sheet.
Bostock and Lees (1938)	1:253 440	Laberge map area geology report.
Tempelman-Kluit (1974)	1:250 000	Geology of the Aishihik Lake map area.
Tempelman-Kluit (1984)	1:250 000	Geology of the Laberge map area.
Carne and Gish (1996)		Outline of geology of Division Mountain area.

Appendix B. *An outline of exploration activity in the Division Mountain area.*

Date	Exploration cbompany	Work performed and highlights	Reference
1903	John Quinn and H.E. Porter	• staked coal near Division Mountain	Yukon Minfile (1997)
1970	Norman H. Ursel Associates Ltd.	• Cub Mountain area; geological mapping, no coal found (NW corner of NTS block 105E/5)	Hunt (1994)
1970, 1971	Arjay Kirker Resources Ltd. for Teslin Exploration Ltd.	• Division and Vowel mountains – bulldozer trenching (7 trenches totalling 167 m near Teslin Creek), mapping, sampling and test I.P. survey over coal outcrops near Teslin Creek • reconnaissance geological mapping, road building • estimated reserves at 41 million tons • exposed aggregate thickness of 18.6 m of coal over an interval approximately 305 m • explored Corduroy Mt, no coal located	Kirker (1971); Craig and Laporte (1972)
1972	Arjay Kirker Resources Ltd. (Archer, Cathro and Associates Ltd.)	• drilled 6 diamond drill holes in Teslin Creek area (totalling 1047 m) • coal seams intersected vary from 4.6 to 5.9 m • 24.8 m aggregate thickness of coal seams > 0.5 m • reserves calculated as 2.8 million tons	Phillips (1973)
1975	Allen Resource Consultants Ltd. (Resoursex Ltd.)	• located coal float on Cub Mountain in gopher holes, believed to be within the Tantalus formation	Allen (1975)
1977	Hill for Cyprus Anvil Mining Corp.	• collected coal samples for analysis	Hunt (1994)
1978	Hill for Utah Mines Ltd.	• collected coal samples for analysis	Hunt (1994)
1978	Manalta Coal Ltd.	failed to locate any additional coal seams	Hunt (1994)
1990-1991	All-North Resources Ltd. and W4 Joint Venture	• trenching and mapping near Teslin Creek	Yukon Minfile (1997)
1990	Geological Survey of Canada	• one 1972 bulldozer trench was remapped and carefully sampled (Teslin Creek) for Beaton et al. report	Beaton et al. (1992)
1992	Beaton et al. (University of Western Ontario)	• petrography, geochemistry and utilisation potential of the Division Mountain coal occurrence (Cairnes Seam)	Beaton et al. (1992)
1993	Cash Resources Ltd. (Allister Peach Geo-Consulting Ltd.)	• drilled 16 holes totalling 1810 m near Teslin Creek • intersected over 28 coal seams > 0.5 m thick • total in situ reserves estimated at 11 139 920 tonnes • hand trenching at Red Ridge exposed 11.4 m coal	Peach (1993); Wengzynowski and Carne (1993, 1994)
1994-1995	Cash Resources Ltd. (Archer, Cathro and Associates Ltd.)	• 5.2 km of excavator trenching • 6034 m of HQ-size diamond drilling in 32 holes • aggregate coal thickness 10 to 32 metres • estimated open pit reserves of 31.7 million tonnes	Carne and Gish (1996)
1996-1997	Cash Resources Ltd. (Archer, Cathro and Associates Ltd.)	• 1667 m of HQ-size diamond drilling in 10 holes • 21 excavator trenches totalling 2695 m at Division and Corduroy mountains • hand trenches southwest of Cub Mountain • raw coal reserves estimated at 54.7 million tonnes	Burke (1998); Gish and Carne (1998)
1998	Cash Resources Ltd. (Archer, Cathro and Associates Ltd.)	excavator trenching at Cub Mountain	Burke (1999)
1999	Cash Resources Ltd. (Archer, Cathro and Associates Ltd.)	RC drilling program	