GEOLOGICAL FIELDWORK

Hydrocarbon potential of Upper Paleozoic strata, eastern Richardson Mountains, northern Mackenzie Mountains and Peel Plateau, Yukon

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ABSTRACT

Upper Paleozoic strata in the eastern Richardson Mountains, northern Mackenzie Mountains and Peel Plateau of the Yukon consist of basinal sediments overlain by a siliciclastic sedimentary wedge derived from the Late Devonian Ellesmerian orogeny. Unconformably overlying Paleozoic strata in the Peel Plateau are Cretaceous sedimentary rocks that were deposited in the foreland basin of the Cretaceous Cordilleran orogeny.

This study, as part of the interdisciplinary “Regional Geoscience Studies and Petroleum Potential, Peel Plateau and Plain” project, examines the sedimentology, stratigraphy and hydrocarbon potential of Upper Paleozoic strata in the Peel region and adjacent Richardson and Mackenzie mountains. Units investigated as part of this study include the Canol (Upper Devonian), Imperial (Upper Devonian) and Tuttle (Upper Devonian-Lower Carboniferous) formations, ‘Cf’ map unit (?Upper Devonian-Lower Carboniferous), and ‘Mo’ map unit (?Upper Devonian-Lower Carboniferous). Preliminary analyses suggest the Canol, Imperial, Tuttle, ‘Cf’ and ‘Mo’ are potential hydrocarbon source rocks for the region. The Tuttle Formation is the best prospective reservoir rock of the Upper Paleozoic strata.

RÉSUMÉ

Les couches du Paléozoïque supérieur dans la partie orientale des monts Richardson, au nord des monts Mackenzie, consistent en sédiments de bassin recouverts d’un biseau siliciclastique dérivé de l’orogenèse ellesmérienne du Dévonien tardif. Des sédiments du Crétacé déposés dans le bassin d’avant-pays de l’orogène de la Cordillère reposent en discordance sur les strates du Paléozoïque.

Cette étude, menée dans le cadre du projet interdisciplinaire d‘Études géoscientifiques régionales et d’évaluation des ressources pétrolières du plateau et de la plaine de Peel, examine la sédimentologie, la stratigraphie et le potentiel pour les hydrocarbures des couches du Paléozoïque supérieur dans la région de Peel et des monts Richardson et Mackenzie adjacents. Les unités examinées dans le cadre de cette étude comprennent les formations de Canol (Dévonien supérieur), d’Imperial (Dévonien supérieur) et de Tuttle (Dévonien supérieur – Carbonifère inférieur), l’unité cartographique «Cf» (?Dévonien supérieur – Carbonifère inférieur) et l’unité cartographique «Mo» (?Dévonien supérieur – Carbonifère inférieur). Les analyses préliminaires suggèrent que les formations de Canol, d’Imperial et de Tuttle ainsi que les unités cartographiques «Cf» et «Mo» constituent des sources potentielles de roche mère pour les hydrocarbures dans cette région. Le Formation de Tuttle constitue la meilleure roche réservoir d’intérêt dans les couches du Paléozoïque supérieur.

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INTRODUCTION

The study is part of the "Regional Geoscience Studies and Petroleum Potential, Peel Plateau and Plain" research project. It is a working partnership that involves the efforts of the Geological Survey of Canada, Northwest Territories Geoscience Office, Yukon Geological Survey, and university and industry affiliates. It is a four-year project that will conclude in 2009.

The aim of the project is to study the regional geology of the Peel Plateau and Plain, including the stratigraphy, sedimentology and depositional history, as well as hydrocarbon potential. As part of this study, we focused on Upper Paleozoic strata that occur in the Yukon portion of the Peel region. These strata were analysed for their petroleum potential including source rock potential, and where applicable, reservoir rock potential.

FIELD INVESTIGATIONS

During summer 2007, fieldwork was conducted on NTS map sheets 106E (Wind River), 106F (Snake River) and 106L (Trail River), between latitude 65° and 67°N and longitude 133° and 136°W (Fig. 1). Four weeks were spent in the region encompassing the Peel Plateau, adjacent eastern Richardson Mountains and northern flank of the Mackenzie Mountains, conducting field investigations of Upper Paleozoic and Cretaceous strata. Upper Paleozoic outcrop is limited to the flanks of the Richardson Mountains and the northern front of the Mackenzie Mountains, while Cretaceous strata are exposed in river cuts in the Peel Plateau. This study is a continuation of fieldwork conducted in 2006 on the eastern flank of the Richardson Mountains (Fraser and Allen, 2007). This paper focuses on investigations of the Upper Paleozoic strata.

Sample collection focused on obtaining representative examples of shale to determine source rock potential and thermal maturation using Rock-Eval pyrolysis and total organic carbon (TOC) analysis, as well as age determination from palynomorphs. Sandstone and conglomerate were collected to examine lithology and to measure reservoir parameters such as porosity and permeability. Other investigations included measuring detailed stratigraphic sections to collect data on stratigraphic thicknesses, determining the nature of contacts between units and interpreting depositional environments.

REGIONAL STRATIGRAPHY

The Peel Plateau and Plain in the Yukon is underlain by a westerly thickening wedge of Phanerozoic sedimentary rock (up to 4.5 km thick) that unconformably overlies a poorly understood Proterozoic succession (Osadetz *et al.*, 2005). Phanerozoic strata in the region are divided into three main depositional systems: 1) Cambrian to Upper Devonian carbonate and shale of the Mackenzie Peel shelf and Richardson trough (Morrow, 1999); 2) an Upper Devonian to Carboniferous clastic wedge that was deposited in a foreland basin of the Yukon and Ellesmerian fold belts associated with the Frasnian to Tournaisian Ellesmerian orogeny (Richards *et al.*, 1997); and 3) Cretaceous marine shelf deposits that were deposited in the foreland basin of the Cordilleran orogen (Dixon, 1992).

Upper Paleozoic strata (specifically Upper Devonian to Lower Carboniferous) for the Richardson Mountains are correlative with the Peel Plateau (Figs. 2 and 3), and consist of the Canol, Imperial and Tuttle formations, with the overlying Ford Lake Shale in the western Richardson Mountains and the 'Cf' map unit in the Peel Plateau. In the northern Mackenzie Mountains, the stratigraphy is structurally complicated, resulting in units being repeated or removed over the length of an exposure. Norris (1982a) amalgamated the Hare Indian, Canol and Imperial formations when mapping NTS area 106F, demonstrating the complexity of their distribution. It is important to note that the Canol and Imperial formations in the northern Mackenzie Mountains are the only units that are correlative with strata on the eastern flank of the Richardson Mountains (Fig. 2). Stratigraphically above this level the relationship between the strata is not clear, though it is likely that the 'Mo' map unit of the Mackenzie Mountains is the stratigraphic equivalent to the Tuttle Formation. The 'Cf' map unit is found both in the northern Mackenzie Mountains and in the Peel Plateau.

Upper Paleozoic strata in the Peel and adjacent regions that were investigated as part of this study will be described in the following sections and include the Canol, Imperial and Tuttle Formations, and 'Cf' and 'Mo' map units.

CANOL FORMATION

The Canol Formation has been documented in the Mackenzie Delta, Kandik Basin, Eagle Plain, Richardson Mountains, Bonnet Plume Basin and Peel Plateau of the Yukon (Morrow *et al.*, 2006; Pigage, 2007). On the Trail

River map sheet, the Canol Formation disconformably overlies the Road River Group and is conformably overlain by the Imperial Formation (Morrow, 1999). On Trail River proper (east Richardson Mountains), the Canol Formation attains a thickness of 225 m, although in the subsurface of Peel Plateau and Plain it is generally much thinner (< 100 m) (Fraser and Hogue, 2007; Pyle *et al.*, 2006). In the Snake River map area (northern Mackenzie Mountains), the distribution and thickness of the Canol Formation is uncertain, as it was amalgamated with the Hare Indian and Imperial formations for the purpose of mapping (Norris, 1982a).

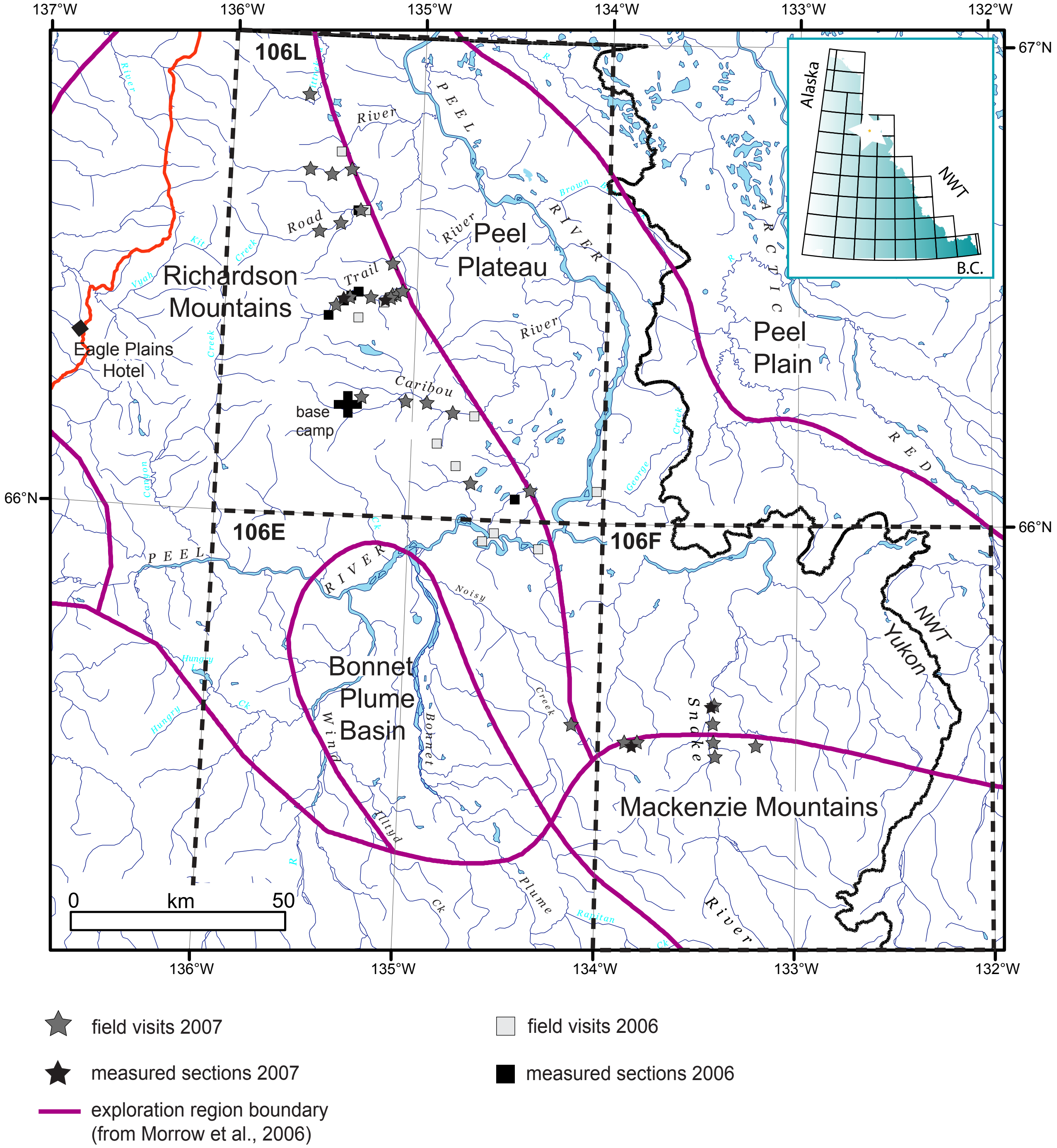

Figure 1. *Location map and general geography of study area.*

The resistant Canol Formation forms canyons on the Trail and Road rivers. In the study area, the Canol Formation consists of dark grey to black, noncalcareous shale and chert coated with a distinctive bright yellow and apple green patina, possibly the mineral jarosite (Aitken *et al.*, 1982). The chert occurs as thin to very thin, even parallel planar beds that are commonly rusty weathered. The chert is separated by thinly to thickly laminated shale that is sooty to very well indurated (Figs. 4a and 4b). The Canol Formation has large elongate carbonate(?) concretions measuring metres across; it also contains small pyrite concretions which are 1 to 2 cm across, but

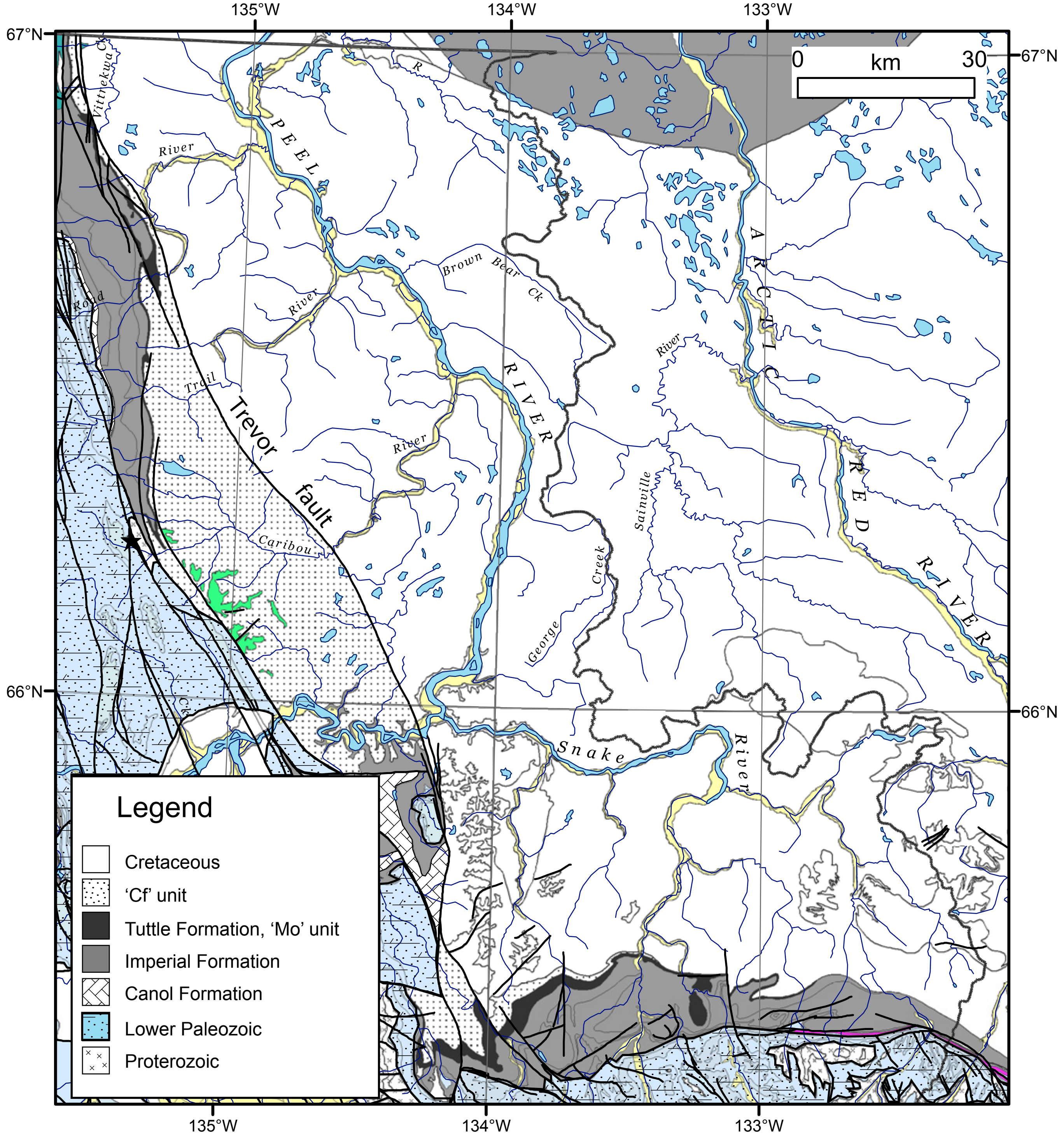

Figure 2. *Geological map of study area. Geology modified from Norris (1981; 1982a,b; Gordey and Makepeace, 2001).*

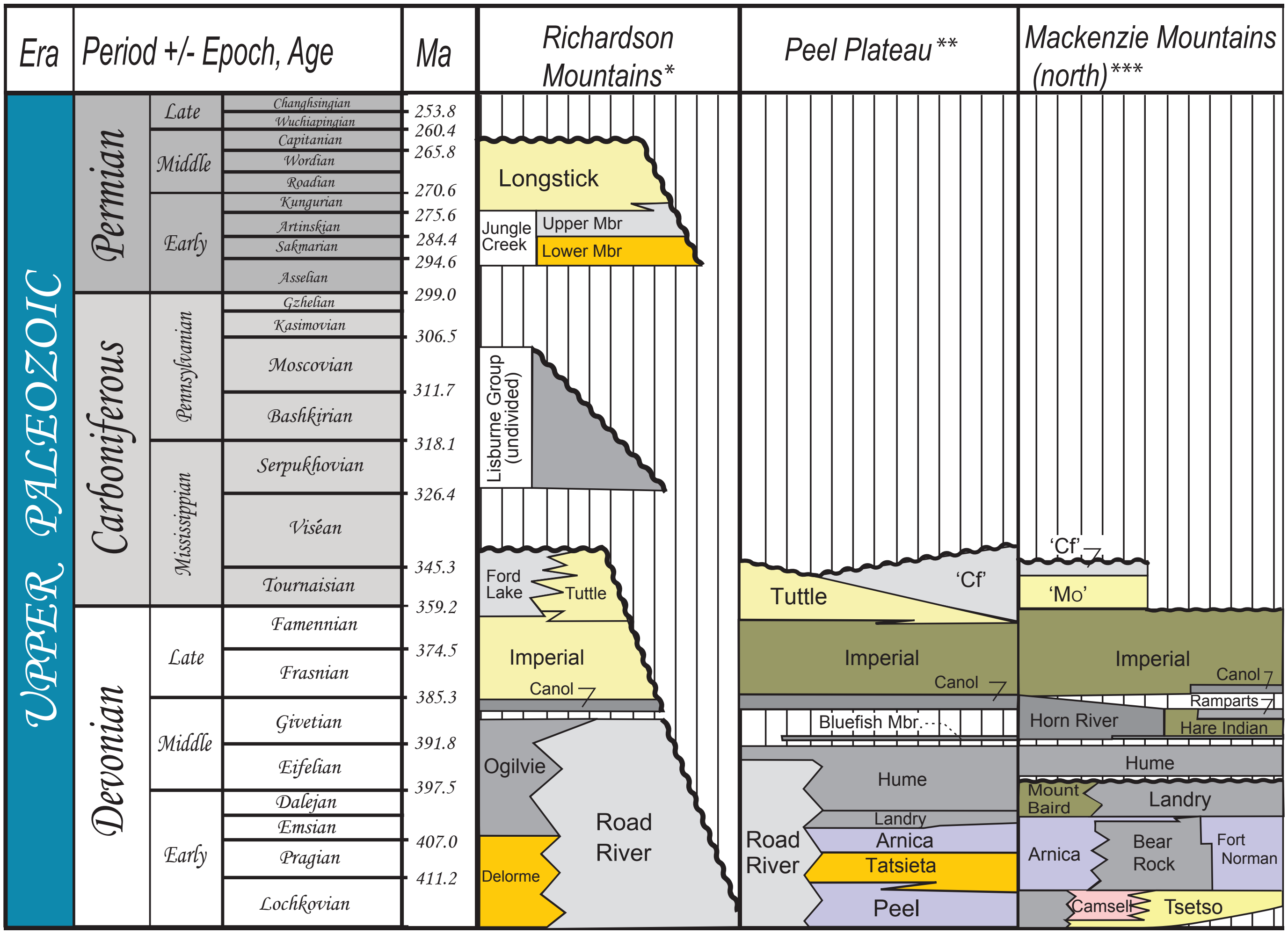

Figure 3. *Stratigraphic column of Upper Paleozoic strata for the three physiographic regions where fieldwork was conducted: the Richardson Mountains, Peel Plateau and Mackenzie Mountains. Ma = million years.*

**from Morrow et al. (2006); **modified from Pigage (2007); ***modified from Morrow et al. (2006)*

***Figure 4. (a)** Typical outcrop of the Canol Formation, Trail River. Note planar, even beds of chert and shale. Large carbonate concretions observed in the far right of the outcrop. **(b)** Close up of the Canol Formation, Trail River, showing planar-bedded shale and chert (thicker beds). Rock hammer for scale is 30 cm long.*

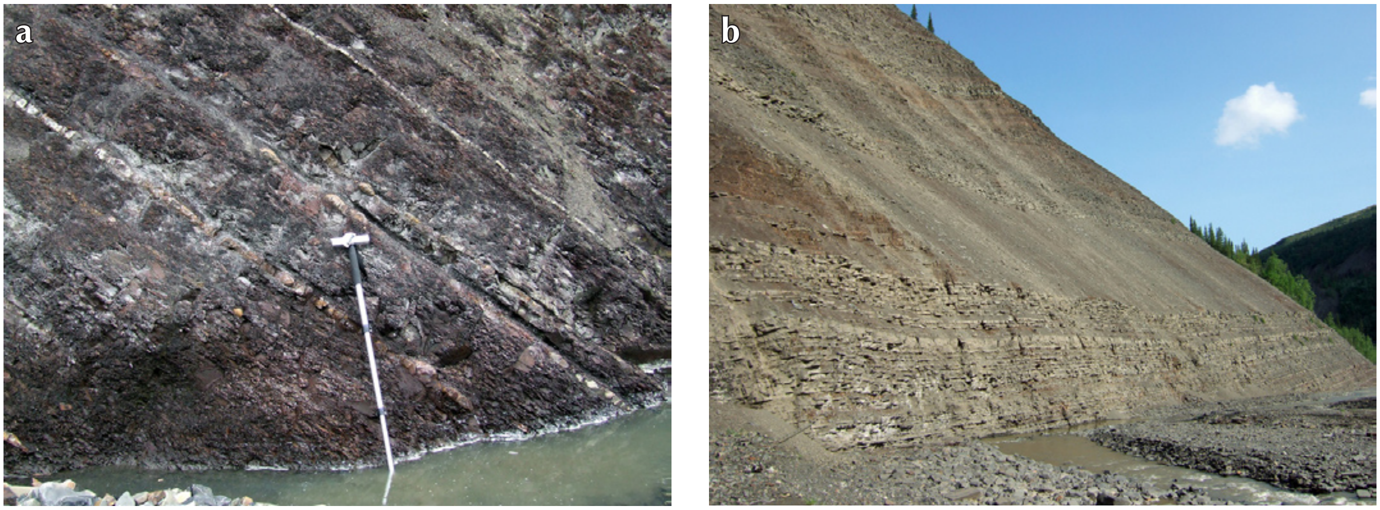

***Figure 5. (a)** 'Lower Imperial' Formation, Trail River. This lower member is characterized by thick intervals of mudstone punctuated by continuous resistant siderite bands, as shown here. Length of pogo for scale is approximately 1.3 m.*
***(b)** 'Upper Imperial' Formation, Tetlit Creek. The upper member consists of interbedded sandstone, mudstone and lesser shale. Sandstone volume increases towards the top of the formation.*

locally up to tens of centimetres. On Road River, the Canol outcrop has a strong sulphurous smell.

The Canol Formation has been dated as late Givetian, but a more likely date is early Frasnian based on palynomorphs from Trail River identified by D.C. McGregor (Norris, 1985). Al-Aasm *et al.* (1996) suggest the Canol was deposited in a deeper marine anoxic to dysoxic setting based on degrees of pyritization (DOP).

IMPERIAL FORMATION

The Imperial Formation extends across northern Yukon from Eagle Plain in the west to the Mackenzie Delta in the east, including the Richardson Mountains, Bonnet Plume and Peel region (Morrow *et al.*, 2006; Pigage, 2007). In the east Richardson Mountains, the Imperial conformably overlies the Canol Formation and is conformably overlain by the Tuttle Formation. In the northern Mackenzie Mountains, the Imperial is mapped together with the Canol and its relation is thus uncertain. Here, it is overlain conformably by the 'Mo' map unit, particularly in the west, and unconformably by the Cretaceous Arctic Red Formation, particularly in the east. The Imperial is 716 m thick at its type section on Imperial River (N.W.T.) (Tassonyi, 1969) and 1461 m of strata were measured on Trail River (Norris, 1968). A maximum thickness of 1909 m is recorded in the Union Amoco McPherson B-25 well, in the southern part of the northern Richardson Mountains (Pugh, 1983).

In the east Richardson Mountains, the Imperial consists of two lithologically different units: a lower mudstone dominated unit and an upper interbedded shale/mudstone and sandstone unit informally referred to in this paper as the 'lower Imperial' and the 'upper Imperial', respectively. The 'lower Imperial' Formation is predominantly medium-grey mudstone with a small percentage of medium-grey thin sandstone beds and siderite bands (Fig. 5a). The mudstone is uniform, structureless and blocky-weathered with rusty fractured surfaces that give the unit an overall reddish hue. The siderite occurs as continuous bands (10 to 15 cm thick) and as nodules within discrete layers. Some nodules contain pyrite and/or calcite(?) septaria.

Sandstone beds increase gradually in abundance and thickness upward in the Imperial Formation, resulting in a more resistant 'upper Imperial' (Fig. 5b). Sandstone within the Imperial Formation is very fine to fine-grained, quartz-rich and well cemented. Thin section investigations of the Imperial reveal quartz and minor chert, with dark, grungy-looking material between the grains which may be calcite and/or siderite. Sedimentary structures include flute marks and load casts at the base of sandstone beds, locally with iron carbonate nodules. The finer grained sedimentary rocks of the 'upper Imperial' include blocky, structureless, grey mudstone and lesser grey shale.

Palynological studies of samples collected on the Trail River suggest that the 'upper Imperial' Formation is

Frasnian to early Famennian? (Late Devonian)[1]. Samples submitted from the 'lower Imperial' on the Trail River contain spores that are very poorly preserved and did not yield a date[1], however in an earlier study, spores identified by D.C. McGregor (reported in Norris, 1985) from the base of the Imperial Formation on Trail River were dated as late Givetian or early Frasnian (Middle-Late Devonian).

Several authors have noted turbidite features in the Imperial Formation (*e.g.,* Norris, 1997; Glaister and Hopkins, 1974; and Glennie, 1963). Paleoflow direction of these sediments is noted as generally from a north, northwest, and lesser west (Hills and Braman, 1978) and southeast source (Pugh, 1983). In the subsurface, clinoforms observed on seismic lines demonstrate an easterly derived sediment source for the Imperial Formation, particularly in the N.W.T. portion of the Peel region, east of Flyaway Creek (Y. Lemieux; W. Zantvoort, pers. comm. 2007).

TUTTLE FORMATION

The Tuttle Formation is described in Fraser and Allen (2007). It is suggested the reader consult this paper for a more comprehensive description of the Tuttle Formation.

The Tuttle Formation has been documented in Eagle Plain, the southern Richardson Mountains, Peel Plateau and the western part of the Peel Plain (Morrow *et al.*, 2006; Pigage, 2007). Some authors suggest the basal contact of the Tuttle with the Imperial Formation is conformable (Pugh 1983), whereas others report that on the Trail River, and possibly elsewhere, it is unconformable (Norris 1985; Braman, 1981). D.K. Norris' (1981) geology map of the Trail River map sheet suggests that the Tuttle is conformably overlain by the 'Cf' map unit. Subsurface studies (*e.g.,* Pugh, 1983; Lutchman, 1977) report the Tuttle as being overlain unconformably by Cretaceous strata. The Tuttle is 874 m thick at the type section in the Peel Y.T. F-37 well (Pugh, 1983). The thickest Tuttle section recorded in the Peel region is 1198 m in the Trail River Y.T. H-37 well.

The Tuttle Formation consists of alternating packages of coarse-grained and finer grained strata (Fraser and Allen, 2007). Coarse-grained intervals are resistant in nature and comprise sandstone with minor conglomerate (Fig. 6a). Sandstone consists predominantly of chert and quartz. Locally the chert is weathered to a porous, chalky white material referred to as 'tripolitic' chert (Shell Canada Ltd., 1964). 'Tripolitic' refers to a light coloured, porous, friable siliceous sedimentary rock which results from the weathering of chert (after Neuendorf *et al.*, 2005). Chert is also observed as variable-coloured clasts (*e.g.,* grey, black, yellow and green). Between the sandstone grains, a white chalky material can locally be observed, which may be a kaolinite pore-filling cement described by Pugh (1983). A very minor amount of mica has also been observed between sandstone grains. Sandstone textures range from

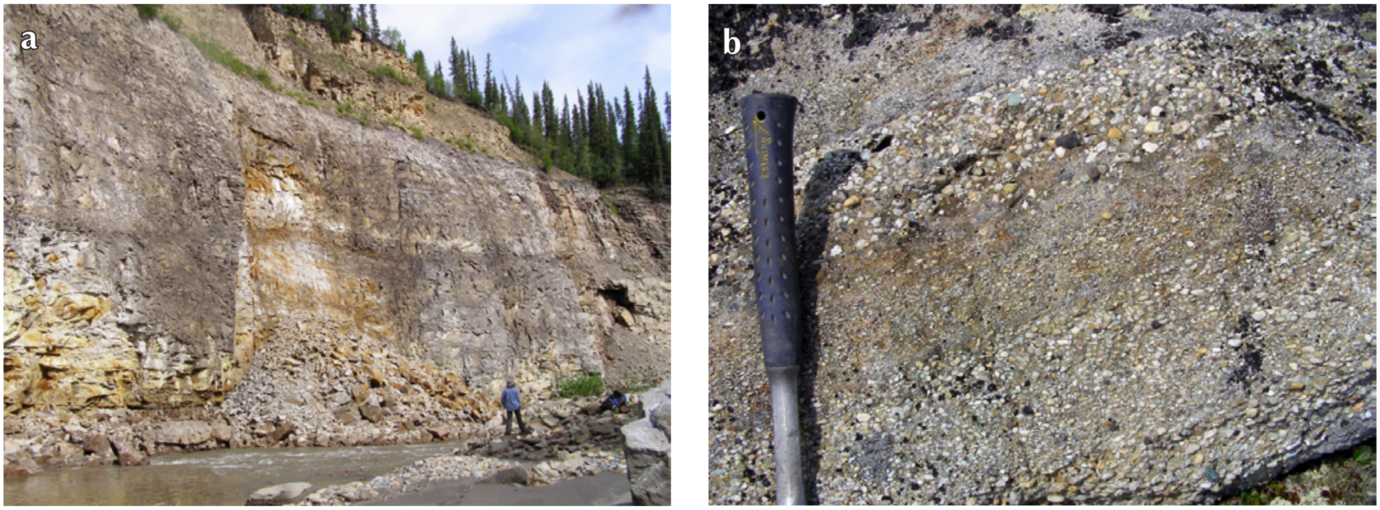

Figure 6. (a) *Outcrop of the Tuttle Formation sandstone, near the Trevor fault on Trail River. Note strata are flat-lying. This is the locality where oil-stained samples were collected. Person for scale in bottom right.* ***(b)*** *Close up of the Tuttle Formation, exposed on a ridge north of Road River. In the northern part of the study area, the Tuttle Formation is coarser grained, commonly consisting of granule to pebble conglomerate, as displayed here. Rock hammer handle for scale is 19 cm.*

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[1] *J. Utting, 2007. Palynological investigations of 25 outcrop samples and 8 core samples from the Upper Paleozoic, Western District of Mackenzie, submitted by T. Allen and T. Fraser, Yukon Geological Survey (NTS 106E/15, 16 and NTS 106L 1,4,6,8,9,10,11). GSC unpublished report 02-JU-2007, 14 p.*

fine to very coarse grained, with sorting mainly poor to moderate. Sedimentary structures were difficult to discern from weathered outcrop exposures.

Conglomerate is not common in the Tuttle Formation, however it does occur as discrete beds up to 60 cm thick within sandstone-dominant intervals, and is more common in the northern part of the Trail River map sheet (Fig. 6b). Fine-grained intervals of the Tuttle Formation, up to 150 m thick, are composed of interbedded shale, siltstone and very fine grained sandstone, giving the strata a 'striped' appearance. The sandstone in these intervals is very thinly bedded, quartz-rich and well indurated, and displays ripples and load casts.

Recent palynological investigations of samples collected from the Trail River map sheet (NTS 106L) suggest the Tuttle Formation is latest Frasnian to late Famennian (Strunian; Late Devonian) in age[1].

Lutchman (1977) suggested the Tuttle Formation (referred to as the 'Mississippian clastic wedge') was of fluvio-deltaic origin based on study of drill core, well logs and drill cuttings. Hills and Braman (1978) have suggested a turbidite setting for the Tuttle Formation on the Trail River. Current field investigations support the interpretation of Hills and Braman (1978): that the Tuttle Formation was deposited within a turbidite setting that began during deposition with the Imperial Formation. Supporting evidence includes: the presence of repeated fining-upward sequences (partial Bouma sequences, with divisions A through DE); load casts, flutes and tool marks on bases of beds; and soft sediment deformation (*i.e.*, intraformational slump folds). Partial Bouma sequences commonly consist of massive to cross-bedded granular conglomerate at the base, grading upwards to cross or parallel-bedded, medium-grained sandstone, with fine to very fine grained sandstone and locally shale or rippled siltstone at the top.

Our fieldwork found that strata on the Trail River mapped by Norris (1981) as map unit 'Cf' is likely the Tuttle Formation, based on lithologic characteristics and age. Portions of map unit 'Cf' on the Caribou and Road rivers also display similarities to the Tuttle Formation, suggesting that detailed mapping of these areas would enhance the geological understanding of Upper Paleozoic strata in this region.

'MO' MAP UNIT

Lower Carboniferous(?) sandstone and shale outcrops along the northern front of the Mackenzie Mountains in the Wind River and Snake River map areas (NTS 106E and 106F). Norris (1981; 1982a,b) mapped these clastic sediments as unit 'Mo'. The 'Mo' map unit unconformably overlies the Imperial Formation and is overlain conformably by a shale-rich unit mapped as 'Cf' by Norris (1982a; see description of 'Cf' in section below), or unconformably by Cretaceous strata. The total thickness of the 'Mo' map unit is difficult to determine due to its discontinuous exposures and folding and faulting in the region.

No published description exists for the 'Mo' map unit, except for the description in the map legends of NTS sheets 106E and 106F (Norris, 1982a,b) which describes it as "sandstone, light grey, medium-grained; shale, dark grey; nonmarine?". More recently, authors have included the 'Mo' map unit with the Tuttle Formation (Gordey and Makepeace, 2001). Figure 18 of Pugh (1983) and Figure 8.11 in Richards *et al.* (1997) suggest that Carboniferous strata, mapped as 'Mo' along the northern front of the Mackenzie Mountains in the vicinity of Snake River, is fine-grained sandstone of the Tuttle Formation.

On the Snake River, the 'Mo' map unit crops out as resistant, very fine to fine-grained sandstone (Fig. 7a) forming a narrowing of the river channel. The sandstone is quartz-rich and very dense. It consists of alternating intervals of rippled, lenticular, thinly bedded sandstone; cross-bedded, thickly bedded sandstone; and minor shale (Fig. 7b). Horizontal and vertical burrows are commonly observed in the rippled sandstone. Other features include coalified plant debris and stylolites draped with black organic(?) material. The section on Snake River has an increase in the percentage of fine-grained siliciclastic rocks upsection.

Thin-section analysis reveals that the sandstone of the 'Mo' map unit is quartz-rich with minor typically non-porous chert. The quartz grains are commonly fused together and where a matrix is present it may consist of carbonate with small amounts of mica and chlorite. Based on this study, the 'Mo' map unit exhibits features that are unique to the Tuttle Formation, including high quartz to chert ratios; substantial quartz cementation; low porosity and permeability values (see hydrocarbon potential discussion below); the presence of carbonate cement; overall small grain size; presence of bioturbation; and well preserved sedimentary structures.

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[1] *J. Utting, 2007. Palynological investigations.*

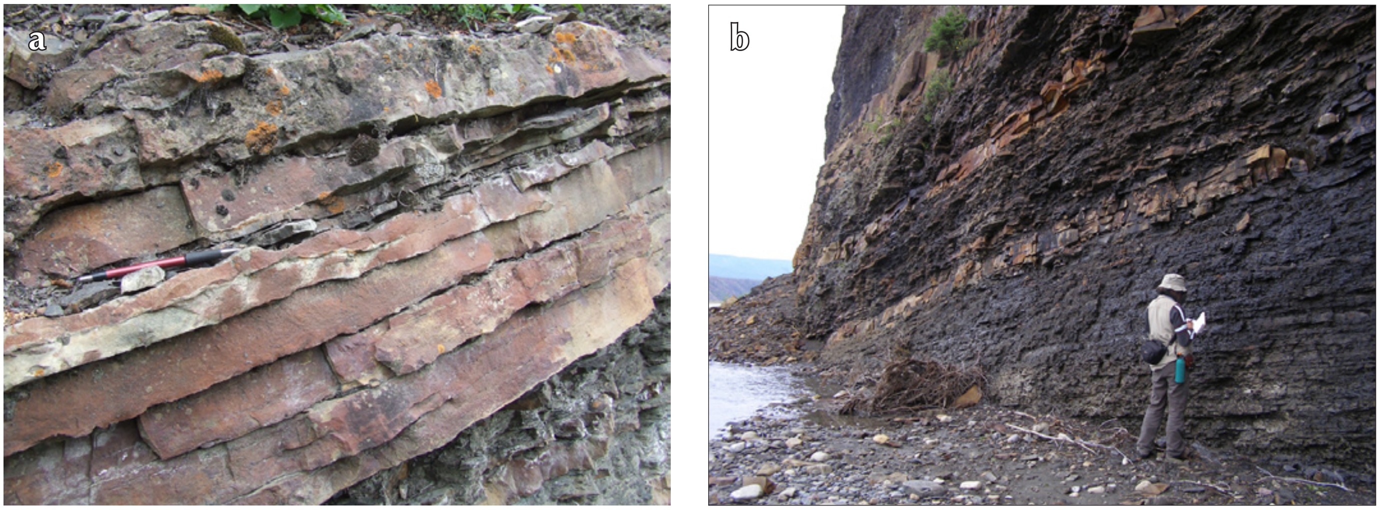

***Figure 7. (a)** Close up of fine-grained sandstone beds typical of the 'Mo' map unit, Snake River. Pencil for scale is 15 cm long. **(b)** Outcrop of 'Mo' map unit, Snake River demonstrating alternating very fine grained rippled sandstone beds (dark grey) and more resistant, fine-grained rippled and cross-bedded sandstone beds (light grey).*

'CF' MAP UNIT

On the Trail River, Snake River and Wind River map sheets a unit overlying and time equivalent to the Tuttle Formation was mapped as 'Cf' by Norris (1981; 1982a,b). 'Cf' is described as "shale, dark grey, silty, concretionary; marine and nonmarine" (Norris, 1981; 1982a,b). Norris (1984) later suggested that this unit is correlative with the Ford Lake Shale.

It is important to note that the 'Cf' map unit is not reported from the Peel subsurface. In subsurface Yukon Peel wells, strata immediately underlying Cretaceous sediments have been assigned to the Tuttle Formation.

Our field investigations show that the lithology of the area mapped as 'Cf' is diverse. On the Trail River, the unit mapped as 'Cf' is Tuttle Formation sandstone and shale. On Caribou River, the mapped 'Cf' unit crops out in different locations as two distinctive packages: a resistant black shale that appears similar to the Canol Formation (Fig. 8a); and interbedded grey shale and fine-grained sandstone (Fig. 8b). The resistant black shale variety of 'Cf' fits nicely with Brabb's (1969a, p. 12) description of the Ford Lake Shale as consisting "predominantly of grayish-black siliceous shale and laminated grayish-black chert that splits with a slabby parting". This lithology was also seen on other tributaries of the Peel River, where it occurs as siliceous, dark grey to black shale coated with a white, yellow or orange patina. Generally, the beds consist of rusty-weathered, alternating shale (<1 cm thick) and chert (<10 cm thick). Due to the resistant nature of this lithology, the outcrop forms cliffs that weather light grey to tan and from a distance look like sandstone. In addition to having a distinctive sulphurous smell, gypsum crystals and pyrite nodules are common. In a number of localities, the outer surface of the shale has been burnt to moderate reddish-brown, presumably from forest fire activity. To date, dating of this shale has been hampered by the lack of pollen or spores found in samples.

The interbedded grey shale and sandstone of the 'Cf' map unit was observed on Caribou River, Noisy Creek (northern Mackenzie Mountains), and possibly the Road and Trail rivers, and is probably the same unit that Richards *et al.* (1997, p. 221) described as "cyclic, marine and nonmarine (deltaic) shale, siltstone, sandstone and coal". Palynological investigations of shale collected above the black shale on Caribou River suggest a late Famennian (Strunian) age (Utting, 2007), which is time equivalent to the Tuttle Formation. The sandstone is commonly fine to medium grained. In places it resembles the lithology of the Tuttle Formation (chert and quartz-rich), but in other areas appears more like the 'Mo' map unit (quartz with lesser chert and carbonate cement). On the Caribou River, sandstone beds are up to 1 m in thickness, and have sharp bases with load casts and flutes. Each sandstone package grades upwards from horizontally bedded fine to medium-grained sandstone, to rippled fine to very fine grained sandstone and siltstone. It is unclear how this interbedded shale and sandstone unit relates to the resistant black shale unit as no contacts between them were observed.

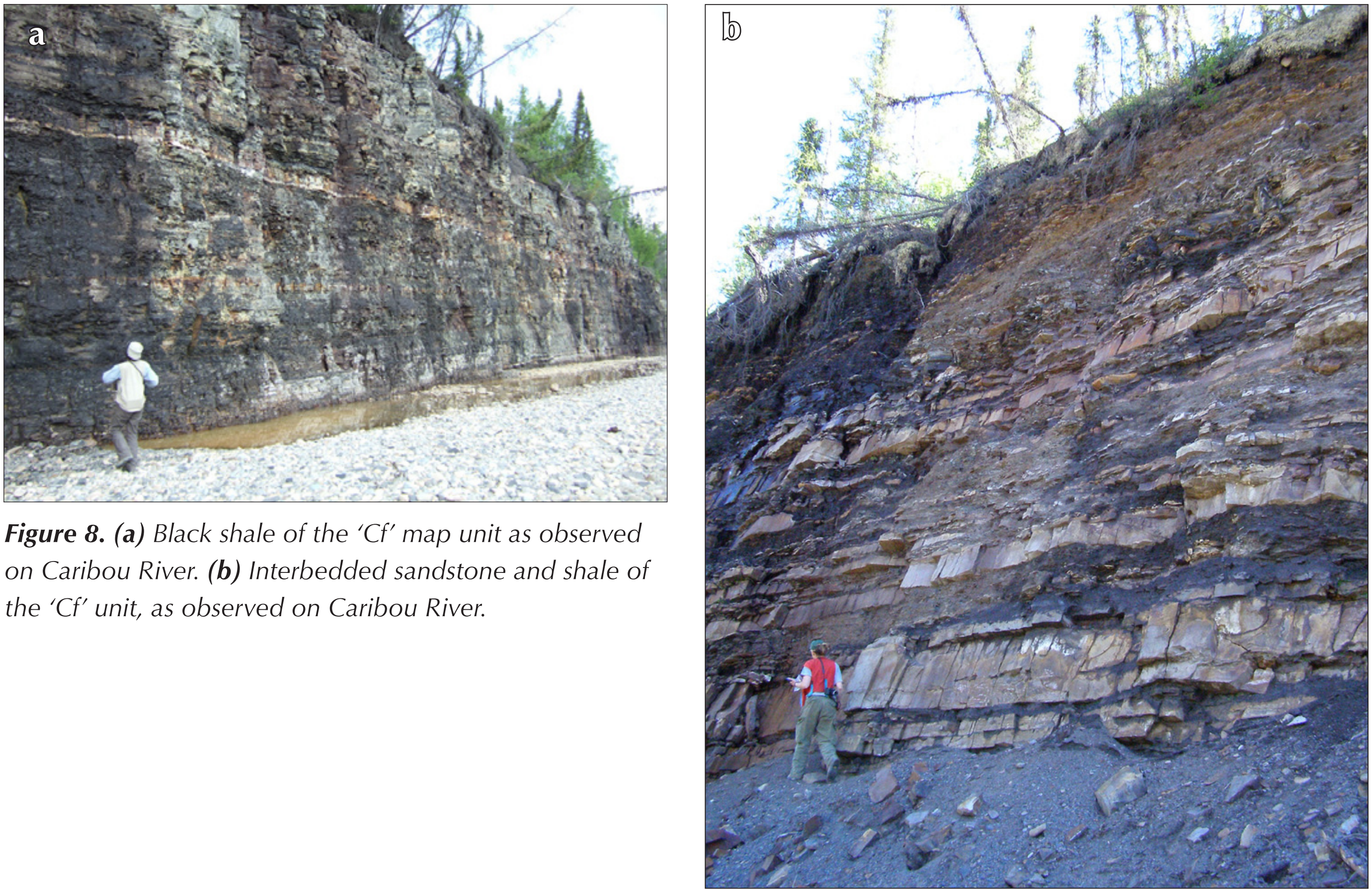

Figure 8. (a) *Black shale of the 'Cf' map unit as observed on Caribou River.* ***(b)*** *Interbedded sandstone and shale of the 'Cf' unit, as observed on Caribou River.*

HYDROCARBON POTENTIAL

As part of this study, shale of the Canol, Imperial and Tuttle formations as well as the 'Cf' and 'Mo' map units were analysed for source rock potential. The coarse-grained fractions of the Imperial and Tuttle formations and the 'Mo' map unit were examined for reservoir rock potential. Included in the results are sample values from both 2006 and 2007. Source rock potential results from 2006 were previously reported in Gal *et al.* (2007) as part of a compilation of data from the Peel region, including results from Yukon and Northwest Territories studies of strata ranging from Proterozoic to Cretaceous.

SOURCE ROCK GEOCHEMISTRY

Source rock potential is based on 124 outcrop samples collected from Upper Paleozoic stratigraphy in the eastern Richardson Mountains, western Peel Plateau, and northern Mackenzie Mountains. The Canol, Imperial and Tuttle formations as well as the 'Mo' and 'Cf' map units were sampled. Rock samples were pyrolyzed using Rock-Eval/TOC to evaluate the type of kerogen, amount of organic carbon and thermal maturity.

Analyses were conducted at the Organic Geochemistry Labs of the Geological Survey of Canada (GSC) Calgary on a Delsi Rock-Eval 6 unit equipped with a TOC analysis module. Results are displayed in Appendix I and Figure 9. The quantity of organic carbon is expressed as weight percent of rock of total organic carbon (TOC). Measured parameters derived from Rock-Eval pyrolysis reported below include S1, which represents milligrams of hydrocarbons that can be thermally distilled from 1 g of rock (mg HC/g rock); S2, which represents milligrams of hydrocarbons generated by pyrolytic degradation of the kerogen in 1 g of rock (mg HC/g rock); and T_{max} (°C) which corresponds to the oven temperature at which the maximum amount of S2 hydrocarbons is generated (Peters, 1986). Other parameters including hydrogen index (HI; S2/TOC x 100) and oxygen index (OI; S3/TOC x 100) are calculated from the measured values. For guidelines on interpreting Rock-Eval and TOC data, refer to Table I.

Table 1. *Rock-Eval interpretative guidelines (modified from Peters et al., 2005).*

Source rock generative potential			
Quality	**TOC (wt.%)**	**S1 (mg HC/g rock)**	**S2 (mg HC/g rock)**
poor	<0.5	<0.5	<0.25
fair	0.5-1	0.5-1	2.5-5
good	1-2	1-2	5-10
very good	2-4	2-4	10-20
excellent	>4	>4	>20
Type of hydrocarbon generated			
Kerogen	**HI (mg HC/g TOC)**	**S2/S3**	**Main product at peak maturity**
I	>600	>15	oil
II	300-600	10-15	oil
II/III	200-300	5-10	oil/gas
III	50-200	1-5	gas
IV	<50	<1	none
Level of thermal maturation			
Maturation	**T_{max} (°C)**	**Ro(%)**	
immature	<435	0.20-0.60	
top of oil window	~435-445*	0.60-0.65	
bottom of oil window	~470	1.35	
postmature	>470	>1.35	
	*varies with type of organic matter		

QUANTITY AND TYPE OF ORGANIC MATTER

Canol Formation

Total organic carbon (TOC) values for Canol Formation strata range from 2.41 to 6.92 wt.% with the exception of one sample that was 0.20 (average 4.21 wt.%; Fig. 9a), with hydrogen index (HI) values from 1 to 15 mg HC/g TOC and oxygen index (OI) values from 4 to 80 mg CO_2/g TOC. The type of organic matter for the Canol Formation could not be determined using the modified van Krevelen (HI versus OI) diagram (Fig. 10a) because values plot too low on this diagram to be meaningful (*i.e.*, indicating thermal maturation is too high; Peters, 1986). Vitrinite reflectance[1] of two samples indicates that Canol strata contain highly weathered amorphous kerogen. Canol Formation strata have a good to very good source rock potential.

Imperial Formation

The Imperial Formation is less promising in terms of a source rock, with TOC values of 0.33 to 7.03 wt.% (average 2.18 wt.% (weight percent)) with almost 60% of the Imperial samples less than 1 wt.% (Fig. 9b). The Imperial Formation comprises type III, gas-prone kerogen, with HI values of 1 to 147 mg HC/g TOC and OI values of 3 to 145 mg CO_2/g TOC (Fig. 10b). Imperial Formation strata on Trail River contain reworked vitrinite particles[1]. The amount and type of TOC suggest that the Imperial Formation has fair to good source rock potential.

Tuttle Formation

TOC values for Tuttle Formation strata range from 0.28 to 40.25 wt.% , although typically the TOC ranges from 1 to 3 wt.% (Fig. 9c). The Tuttle Formation contains type II, oil- and gas-prone and type III, gas-prone kerogen, with HI values of 31 to 458 mg HC/g TOC, and OI values of 4 to 107 mg CO_2/g TOC (Appendix I and Fig. 10c). Tuttle strata on Road River are liptinite-rich with high amounts of sporinite and evidence of hydrocarbon fluid inclusions in

[1] *Organic Geochemistry and Organic Petrology Labratory (OGOPet Lab), pers. comm., 2007. Coal Maceral and Vitrinite Reflectance Database (J. Reyes, analyst), Geoscience Data Repository, Earth Sciences Sector, Natural Resources Canada, Government of Canada.*

some quartz fractures[1], which supports a type II kerogen type. Bitumen, exudatinite and resinite are also present as well as reworked inertinite and pyrobitumen[1]. The unit has good to very good source rock potential for oil and gas. Oil-stained sandstone samples collected on Trail River have S1 values up to 6.8 mg/g rock.

'Mo' map unit

The 'Mo' map unit has TOC values ranging from 2.10 to 11.31 wt.% (average 4.17 wt.%), suggesting the strata are favourable in terms of source rock potential (Fig. 9d). The organic matter is type III, or gas-prone, based on the HI values (40 to 130 mg HC/g TOC) and OI values (7 to 34 mg CO_2/g TOC) (see Appendix I and Figure 10d.)

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[1] *OGOPet Lab, 2007. Coal Maceral and Vitrinite Reflectance.*

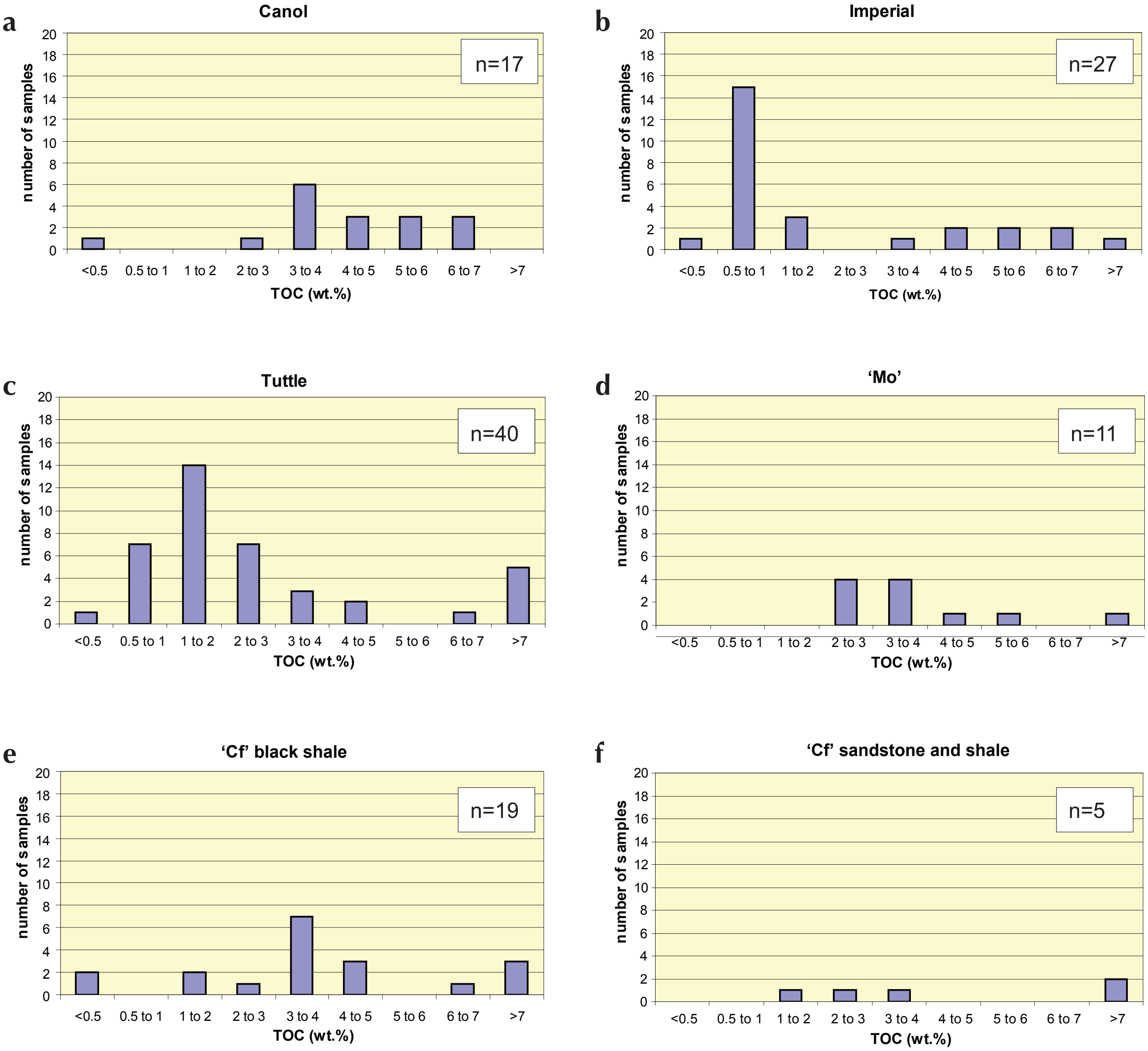

Figure 9 (a-f). *Total Organic Carbon content (TOC) by geological unit. See Table 1 for interpretative guidelines.*

'Cf' map unit

The 'Cf' map unit black shale contains high TOC values, ranging from 1.46 to 12.17 wt.% (average 4.15 wt.%; Fig. 9e). Organic matter within the 'Cf' black shale comprises type II, oil- and gas-prone kerogen, and type III, gas-prone kerogen, with HI values ranging from 26 to 326 mg HC/g TOC and OI values ranging from 3 to 500 mg CO_2/g TOC (Fig. 10e). Only two samples yielded OI values over 57. The 'Cf' black shale has good to very good source rock potential for oil and gas. S1 values for nine of the 'Cf' black shale samples are over 1 mg/g rock, also suggesting a good to excellent generative potential (Peters, 1986). TOC values for the 'Cf' interbedded sandstone and shale unit range from 1.19 to 12.43 wt.% (Fig. 9f), with HI values of 61 to 273 mg HC/g TOC and OI values of 3 to 31 mg CO_2/g TOC (see Appendix I and Fig.10f).

THERMAL MATURATION

T_{max} values can be used to estimate the level of thermal maturity of sedimentary sequences, however caution should be used with samples that have S2 values below 0.2 mg HC/g rock as they are unreliable due to the broad nature of their S2 peak (Peters, 1986). Thermal Alteration Index (T.A.I.) and vitrinite reflectance are also useful thermal maturity indicators. T.A.I. corresponds to maturity-induced colour changes in organic matter (miospores) under the microscope in transmitted light (Staplin, 1969). Vitrinite reflectance (R_o) was conducted by the Organic Geochemistry and Organic Petrology Laboratory at the GSC Calgary.

The overall maturity trend on the Trail River map sheet shows that the thermal maturity of geologic units increases from east to west towards the Richardson Mountains.

The Canol Formation along the eastern Richardson and northern Mackenzie mountains, the oldest strata examined in the study area, is within the dry gas zone in terms of hydrocarbon generation at surface. T_{max} values for the Canol Formation are largely unreliable as the S2 values are all below 0.2 mg HC/g rock (Peters, 1986). However, vitrinite reflectance results for Canol Formation strata (on Trail River) from the same section are 1.81%R_o, and indicate Canol strata are in the dry gas zone.

For the same region, the overlying Imperial Formation strata also lie within the dry gas zone. Here, T.A.I. values for all Imperial Formation samples submitted are consistently 3+/4- = R_o% 1.85[1] (dry gas zone) and a single vitrinite reflectance sample measured 1.58%R_o[2]. Spores identified by D.C. McGregor from the Imperial Formation on Trail River were black, indicating that they had undergone severe thermal alteration (Norris, 1997).

At surface, there appears to be a shift in the thermal maturity of the Tuttle Formation and 'Cf' strata compared to the underlying units, from the dry gas zone to the oil window. This may be a reflection of older strata (Canol and Imperial) having been subjected to greater burial depths, variations in the type of organic matter, or the shift may be related to the proximity to deformation along the mountains. Organic material in the Imperial and Tuttle formations includes common exinous, woody and coaly fragments[1], suggesting that the type of organic matter is not the reason for the abrupt change in thermal maturation values between the Imperial and Tuttle formations. The proximity to deformation along the Richardson Mountains is likely the explanation, as further to the south on the Peel River, as well as in subsurface to the east, Imperial strata are less thermally altered and are within the oil window.

Tuttle Formation strata range from thermally immature with respect to hydrocarbon generation to within the oil window. T.A.I. values for the Tuttle are all 2= R_o% 0.55[1] (oil window). These values are consistent with T_{max} values (403 to 460°C) and vitrinite reflectance results (0.61 to 0.65%R_o[2]. During our field investigations we collected a number of oil-stained sandstone samples from Trail River. Tuttle Formation strata consist of type II/III, oil- to gas-prone source rocks that at surface are just entering the oil window.

With the exception of samples from Peel River which are anomalous, the overlying and possibly time equivalent(?) 'Cf' map unit either ranks within the oil window or is just entering the oil window (*i.e.*, T_{max} values range from 432 to 444° and 431 to 438°C). These values are consistent with T.A.I results that are all 2= R_o% 0.55[1] (oil window) (Utting, 2007) and vitrinite reflectance values that are 0.65 to 0.78%R_o[2].

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[1] *J. Utting, 2007. Palynological investigations.*

[2] *OGOPet Lab, 2007. Coal Maceral and Vitrinite Reflectance.*

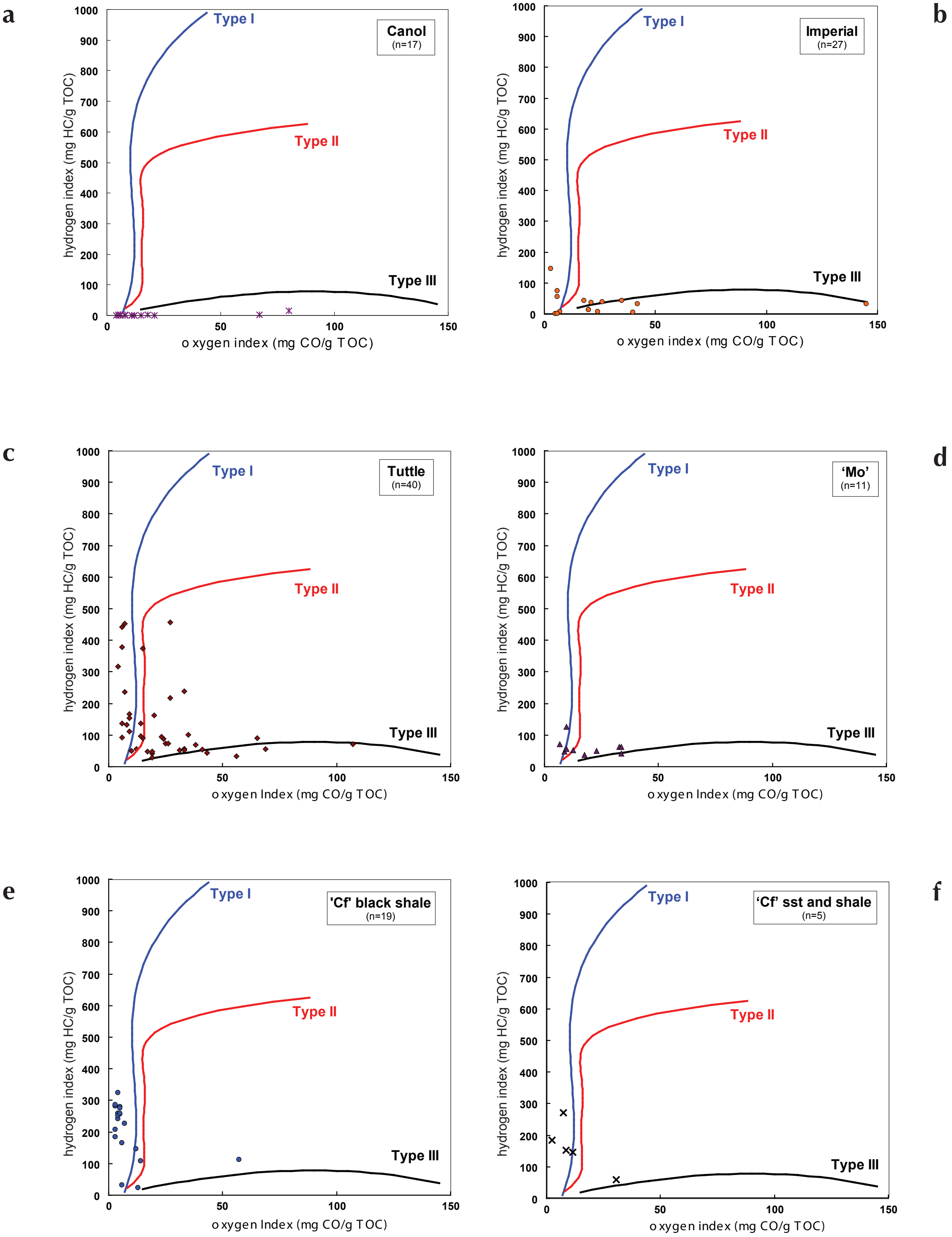

Figure 10 (a-f). *Hydrogen index (HI) versus oxygen index (OI) cross plots for each geologic unit examined. See Table 1 for interpretative guidelines.*

RESERVOIR ROCK POTENTIAL

Reservoir rock potential is based on coarse-grained outcrop samples of Imperial Formation, Tuttle Formation and the 'Mo' map unit analysed for determination of porosity and permeablility. Samples were submitted to AGAT Laboratories, Core Services Division in Calgary using standard procedures of AGAT Laboratories. All results are reported in AGAT Laboratories (2006; 2007)[1]. Thin sections, impregnated with blue epoxy to highlight porosity, were also examined for their detailed reservoir characteristics.

In addition to outcrop samples, eight subsurface samples from drill core were also examined for their reservoir rock potential. These samples were taken from the coarse-grained fraction of the Tuttle Formation. Six of these samples were taken from the Peel River Y.T. L-01 well, and one each from the Peel River Y.T. K-09 and Peel River Y.T. J-21 wells. Cored intervals in Peel wells are rare and these samples represent all available cored intervals from Upper Paleozoic formations in Yukon Peel region wells. These samples were made into thin sections, impregnated with blue epoxy, in order to examine lithology and porosity characteristics.

Imperial Formation

Imperial Formation sandstone observed in the eastern Richardson Mountains is very fine to fine-grained, and is characterized by quartz with minor chert lithology. Lab analysis of three outcrop samples show that the Imperial Formation has negligible porosity and permeability values (Fig. 11a). Thin-section analyses from five samples confirm the 'tight' nature of these sandstones. Depending upon the sample, porosity in Imperial Formation sandstone is restricted by a combination of the following: fused quartz grain boundaries with overgrowths; infill with silt and clay grains, as well as clay minerals; and calcite cement.

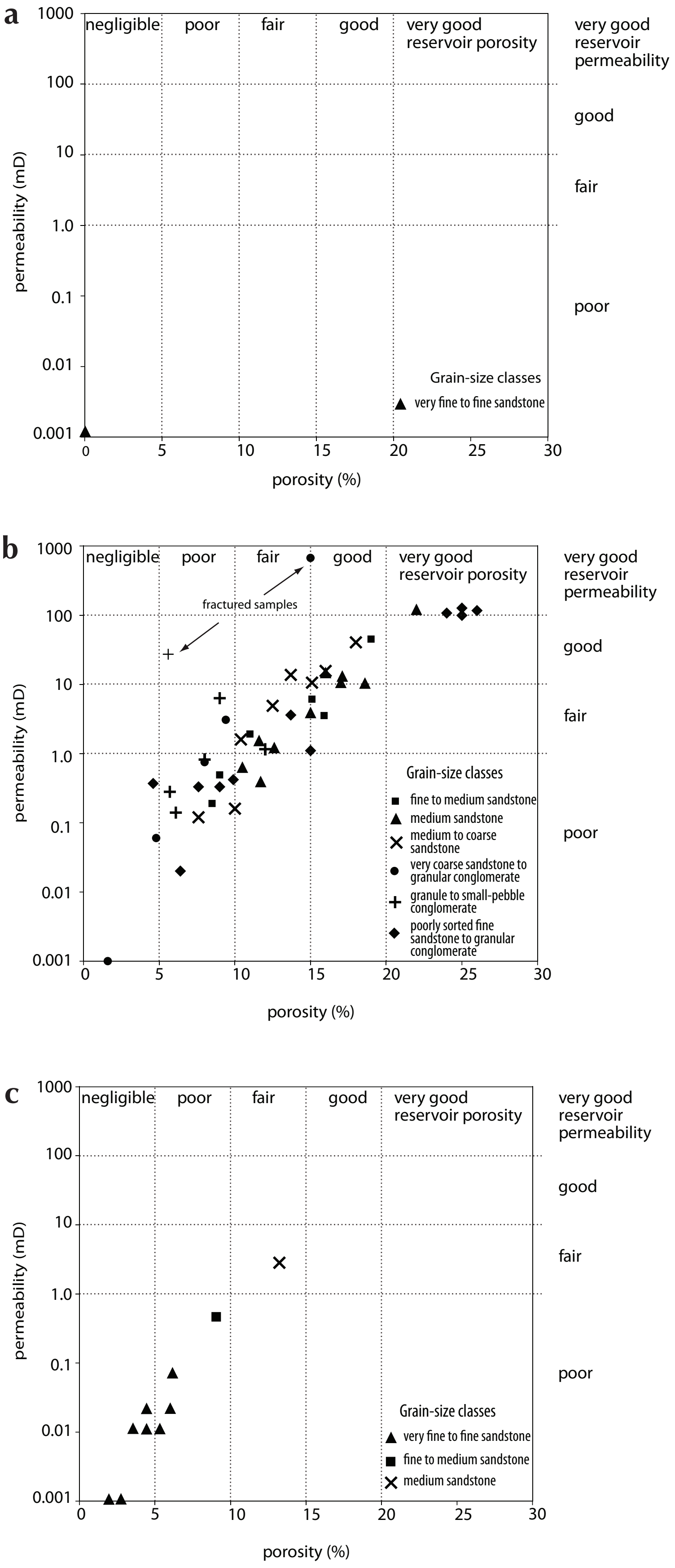

Figure 11. *Reservoir potential cross plots.* ***(a)*** *Imperial Formation,* ***(b)*** *Tuttle Formation, and* ***(c)*** *'Mo' map unit. Reservoir classes after Levson (2001).*

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[1] *AGAT Laboratories, 2006. Final core analysis report: Outcrop samples miscellaneous locations. Prepared for the Yukon Geological Survey, File RC12795, 6 p.*

AGAT Laboratories, 2007. Final core analysis report: Whitehorse Yukon misc outcrop samples. Prepared for the Yukon Geological Survey, File RC30014, 6 p.

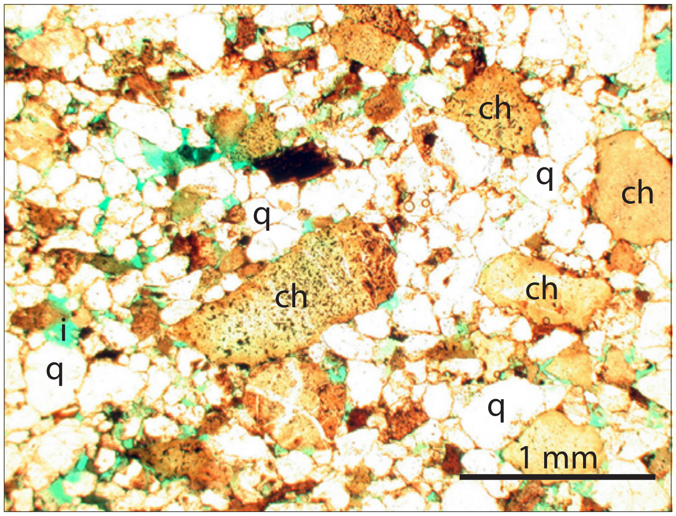

Figure 12. *Thin-section sample from the Tuttle Formation on Trail River. Chert (ch) in this sample is porous and is stained with hydrocarbons, in contrast to quartz (q) which is impermeable. There is also intergranular porosity in this sample (i).*

Tuttle Formation

The coarse fraction of the Tuttle Formation has a wide range of grain sizes ranging from fine-grained sandstone to small pebble conglomerate. Forty-six field samples, divided into six grain-size classes, were analysed for porosity and permeability with results plotted on Figure 11b. Porosity ranges from 2 to 26%, with permeability ranging between 0 and 127 mD. For the Tuttle Formation, reservoir potential based on porosity and permeability varies from negligible to very good using reservoir classes by Levorson (2001). From this cross-plot, it is apparent that grain size does not significantly influence porosity and permeability values. Thin-section analysis of Tuttle sandstones from outcrop show the presence of intergranular porosity as well as intragranular porosity within weathered chert grains (see discussion below). Oil-stained chert grains and what are likely small oil accumulations can be found in the pores of some Tuttle samples (Fig. 12). In samples with lower porosity, the quartz to chert ratio is higher, and primary porosity is commonly restricted by quartz overgrowths and infill by what appear to be clay minerals.

The eight Tuttle sandstone core samples were analysed using imaging software to determine an area percent of the thin section that is porous (*i.e.*, highlighted as blue when impregnated with epoxy). Eight photographs were made from each thin section, and an average porosity was determined for each sample. Results from this study are shown in Figures 13a, b and c.

Six sandstone samples were analysed from the Peel River Y.T. L-01 well between depths of 4455.8' and 4483.2' (1358.1 to 1366.5 m; Fig. 13a). Average porosity ranged from 11.1% to 24.0%. Average grain size over this interval is fine- to medium-grained sand. In samples with lower porosity, primary porosity appears to be restricted by quartz overgrowths, calcite cement, and fused grain boundaries. Fused grain boundaries are more abundant between quartz grains, rather than between chert grains. Where chert grains are fused with one another, the contact does not appear to be as tight as between a quartz-quartz contact, sometimes allowing a thin vein of porosity. In these zones of lower porosity, some stylolites can be observed. In areas of higher porosity, secondary porosity plays an important role, particularly due to the weathering of chert grains (Fig. 14). Chert grains weather both around their margins, as well as within their boundaries. The dissolution of these grains, combined with any primary porosity, appears to provide a well connected pore distribution thereby enhancing permeability.

Sandstone from the Peel River Y.T. K-09 well was sampled at a depth of 4391.5′ (1338.5 m) from a fine-grained sandstone (Fig. 13b). Average porosity was 7.9%. Porosity from this sample is mainly secondary from the dissolution of chert grains and includes both porosity within and between chert grains. In some cases, entire chert grains have been weathered, resulting in large pore spaces. This sample is generally well compacted with boundaries between quartz grains well fused. A small amount of porosity in this sample has been reduced by calcite cement.

One fine-grained sandstone sample was analysed from the Peel River Y.T. J-21 well at a depth of 2020.7′ (615.9 m; Fig. 13c). Average porosity from this sandstone was <3%. This sandstone was very well compacted with an abundance of fused grain boundaries both between chert and between quartz grains. The small amount of porosity that is observed is associated with the weathering of chert grains. This secondary porosity appears to be greatly reduced due to both calcite and siderite cement, found both within and between chert grains. This sample has a higher quartz to chert ratio than the other subsurface samples, and quartz overgrowths also play a role in porosity reduction.

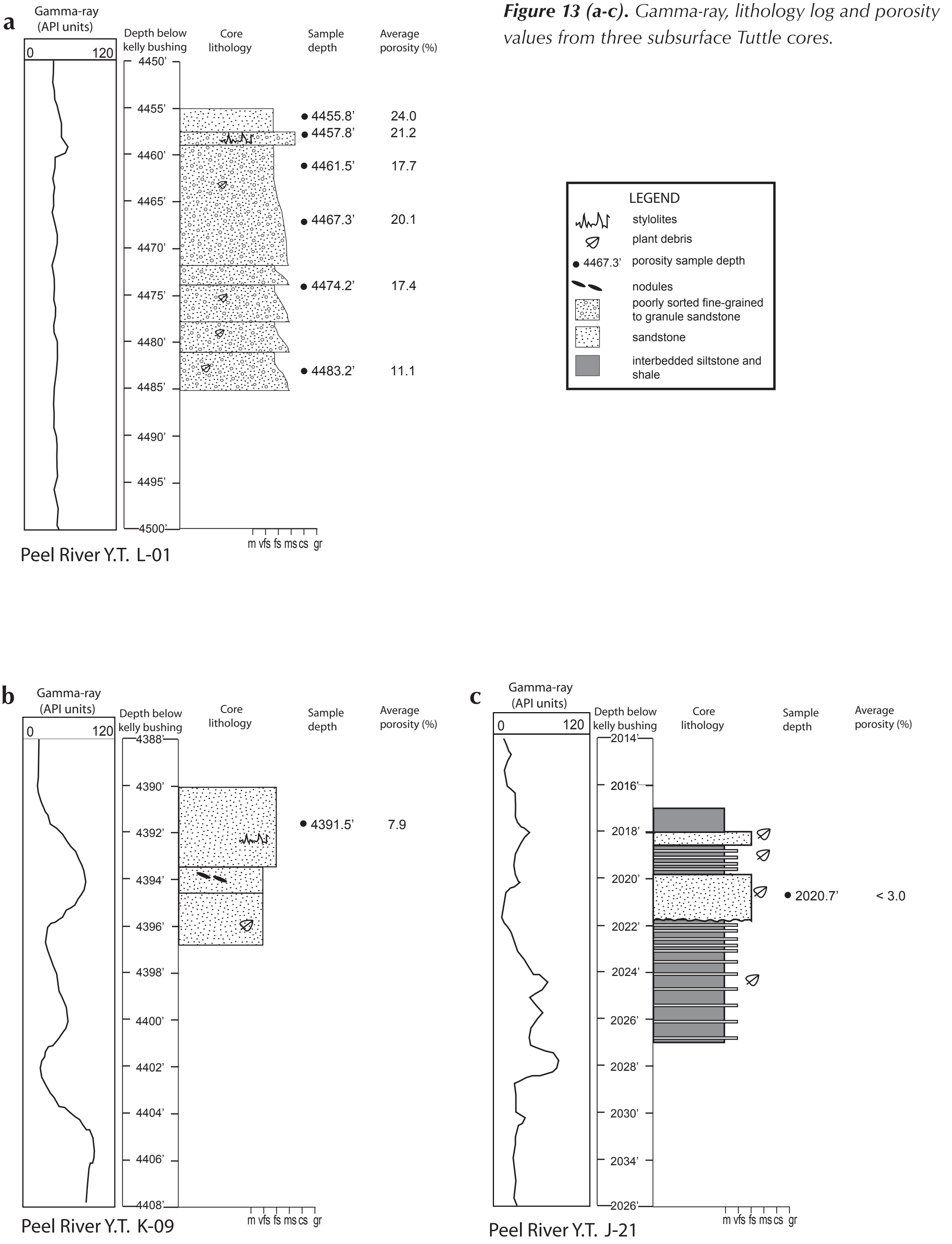

Figure 13 (a-c). *Gamma-ray, lithology log and porosity values from three subsurface Tuttle cores.*

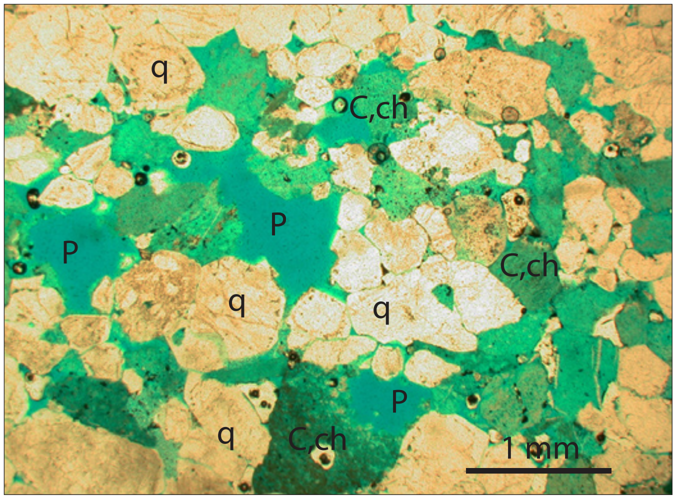

Figure 14. *Thin section of the Tuttle Formation demonstrating both intergranular (P) and intragranular (C) porosity. Tuttle sandstone typically consists of quartz (q) and chert (ch). The chert grains tend to be porous and locally contain hydrocarbons.*

From observation of both outcrop and subsurface samples, porosity within the Tuttle Formation is both intragranular and intergranular, both greatly influenced by the presence of weathered chert. The higher the percentage of chert, the greater the rock's ability to reduce the effects of quartz cementation, and to provide secondary porosity from weathering. As previously stated, weathered chert within the Tuttle Formation has been referred to as 'tripolitic' (Shell Canada Ltd., 1964). Our investigation shows that the presence of 'tripilotic chert' in the Tuttle Formation greatly enhances its reservoir capabilities.

'Mo' map unit

The 'Mo' map unit, is typically very fine to fine-grained in texture. Ten field samples were analysed for porosity and permeability with samples ranging from very fine to medium-grained sandstone. From the analyses conducted, reservoir characteristics of the 'Mo' are generally negligible to poor, with only one sample rating as fair (Fig. 11c). Porosity values ranged from 2 to 13%, with permeability ranging from 0 to 2.6 mD. On this cross-plot, grain size appears to influence reservoir characteristics with medium sandstone units having better reservoir prospects. Thin-section analysis of 'Mo' sandstone displays generally a well compacted quartz-rich sandstone with fused grain boundaries and minor porosity. Primary porosity, where present, is commonly reduced by quartz overgrowths, clay minerals, and/or calcite cement.

OIL STAINS AND HYDROCARBON SEEPS

Oil staining was noted in porous sandstone of the Tuttle Formation on Trail River, near the Trevor fault. These samples were not in outcrop, instead were scattered along the river bed below an active rock fall.

Oil-stained sandstone samples were stained dark brownish grey, very porous (16+%) and smelled strongly petroliferous (Fig. 15). Grain size of the samples ranged from fine to coarse, with sorting normally poor to moderate. These samples have been submitted to the Organic Geochemistry Laboratory at the GSC Calgary for analysis to determine the type of hydrocarbon present, the source rock for the hydrocarbons from the identification of biomarkers, and the thermal maturity.

In the vicinity of the Trevor fault zone on Trail River, there is a very strong sulphur smell in the air over several kilometres that can be detected from a helicopter. Figure 16a shows the surface expression of what appears to be Late Devonian to Early Mississippian Tuttle Formation sandstone thrust over possible Cretaceous shale (palynological dating from the shale is in progress). In the area, the Tuttle Formation sandstone is locally coated with a yellowish orange and white popcorn-like coating, particularly along fractures and joints (Fig. 16b). In addition, the rocks in the river are locally coated in a whitish-grey residue. This evidence suggests that there is a gas leak from the Trevor fault on Trail River. Continuing research into this phenomenon will be conducted in summer 2008.

Figure 15. *Tuttle Formation sandstone from Trail River exhibiting hydrocarbon staining. Unstained sandstone is on the far right of sample.*

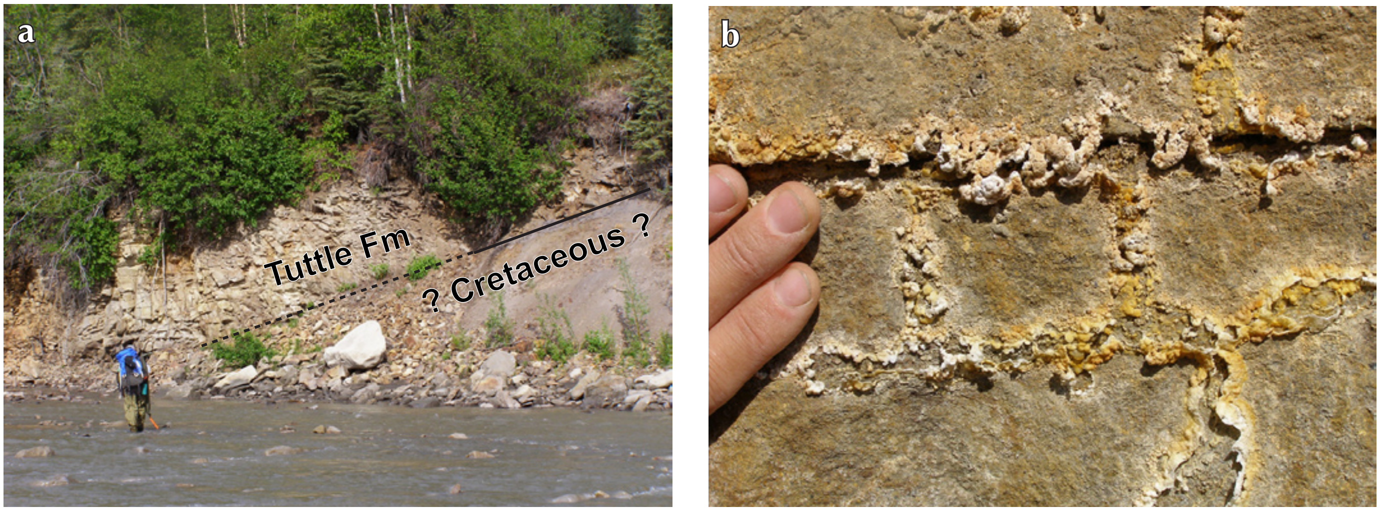

Figure 16. (a) *Surface expression of what may be the Trevor fault on Trail River. This view of the north side of the river shows Tuttle Formation sandstone thrust eastwards over probable Cretaceous shale.* ***(b)*** *Chemical and/or biological precipitate on Tuttle Formation outcrop in the Trevor fault zone, Trail River, indicating a possible gas leak.*

SUMMARY

The aim of the "Regional Geoscience Studies and Petroleum Potential, Peel Plateau and Plain" research project is to study the geology and hydrocarbon potential of the inter-territorial Peel region. This specific project is investigating the Upper Paleozoic geology and hydrocarbon potential in the Yukon portion of the study area. Other projects involved with this study are currently underway and can be viewed on the NWT Geoscience office website[1].

Upper Paleozoic geology in the Yukon Peel region consists of the Canol, Imperial and Tuttle formations, and 'Cf' and 'Mo' map units. These strata span the Late Devonian to Early Mississippian time interval. The Canol Formation is a basinal shale that is overlain by a siliciclastic sedimentary wedge derived from the Late Devonian Ellesmerian orogeny. Sediments of the clastic wedge include the Imperial and Tuttle formations, and overlying 'Cf' map unit in the eastern Richardson Mountains, Peel Plateau and northern Mackenzie Mountains. The 'Mo' map unit is also observed in the northern Mackenzie Mountains and may be the southern extension of the Tuttle Formation.

Shale from the Canol, Imperial and Tuttle formations, and 'Cf' and 'Mo' map units were analysed for source rock potential. All of these formations have good TOC values and thus have the ability of producing hydrocarbons under proper conditions. Thermal maturation analyses from outcrop indicate that the Canol and Imperial formations are post-mature to within the gas window, while the Tuttle Formation and 'Cf' unit are immature to within the oil window.

Sandstone from the Imperial and Tuttle formations, and 'Mo' map unit were analysed for reservoir rock potential including porosity and permeability. Conglomerate of the Tuttle Formation was also included in this analysis. Based on this study, the Tuttle Formation has the best reservoir potential, especially when it contains a substantial proportion of tripolitic (porous) chert. Reservoir potential of Tuttle surface samples ranged from negligible to very good, with values in some samples exceeding 25% porosity and 100 mD for permeability. Subsurface porosity values from the Peel River Y.T. L-01 well range from 11 to 24% from Tuttle Formation core. From the northern Mackenzie Mountains, the 'Mo' map unit has fair reservoir potential at best, with better prospects in medium-grained sandstone as opposed to fine or very fine. The Imperial Formation has no reportable reservoir properties from samples obtained in the east Richardson Mountains and Yukon portion of the northern Mackenzie Mountains.

Further studies in the Peel region are recommended, including detailed bedrock mapping and structure analysis. A number of questions remained unanswered concerning the distribution and variability of the 'Cf' map

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[1] *www.nwtgeoscience.ca/petroleum/PeelPlateau.html*

unit, and the relationship of the 'Mo' map unit to the Tuttle Formation. The strata along the northern Mackenzie Mountains appear to be much more complex than mapped during Operation Porcupine (Norris, 1982a,b). Further fieldwork is warranted in order to sort out the stratigraphy and distribution of units in this area.

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REFERENCES

Aitken, J.D., Cook, D.G. and Yorath, C.J., 1982. Upper Ramparts River (106G) and Sans Sault Rapids (106H) map areas, District of Mackenzie; Geological Survey of Canada, Memoir 388, 48 p.

Al-Aasm, I.S., Morad, S., Durocher, S. and Muir, I., 1996. Sedimentology, C-S-Fe relationships and stable isotopic compositions in Devonian black mudrocks, Mackenzie Mountains, Northwest Territories, Canada; Sedimentary Geology, vol. 106, p. 279-298.

Brabb, E.E., 1969. Six new Paleozoic and Mesozoic formations in east-central Alaska. U.S. Geological Survey, Bulletin, 27 p.

Braman, D.R., 1981. Upper Devonian-Lower Carboniferous miospore biostratigraphy of the Imperial Formation, District of Mackenzie. Ph.D. thesis, University of Calgary, 377 p.

Dixon, J., 1992. A review of Cretaceous and Tertiary stratigraphy in the Northern Yukon and adjacent Northwest Territories. Geological Survey of Canada, Paper 92-9, 79 p.

Fraser, T.A. and Allen, T.A., 2007. Field investigations of the Upper Devonian to Lower Carboniferous Tuttle Formation, eastern Richardson Mountains, Yukon. *In:* Yukon Exploration and Geology 2006, D.S. Emond, L.L. Lewis and L.H. Weston (eds.), Yukon Geological Survey, p. 157-173.

Fraser, T.A. and Hogue, B., 2007. List of Wells and Formation Tops, Yukon Territory, version 1.0, Yukon Geological Survey, Open File, 2007-5, 1 p. plus spreadsheet.

Gal, L.P., Allen, T.L., Fraser, T.A., Hadlari, T., Lemieux, Y., Pyle, L.J. and Zantvoort, W.G., 2007. Rock-Eval 6/TOC analyses from outcrop samples in northern Mackenzie Mountains, eastern Richardson Mountains, and southern Peel Plateau and Plain, Northwest Territories and Yukon, Canada; Northwest Territories Geoscience Office, NWT Open Report 2007-002/Yukon Open File 2007-1, 11 page report, Microsoft Excel® spreadsheet and ESRI ArcView® files.

Glaister, R.P. and Hopkins, J., 1974. Turbidity-current and debris-flow deposits. *In:* Use of sedimentary structures for recognition of clastic environments, M.S. Shawa (ed.), Canadian Society of Petroleum Geologists, p. 23-38.

Glennie, K.W., 1963. An interpretation of turbidites whose sole markings show multiple directional trends. Journal of Geology, vol. 71, p. 525-527.

Gordey, S.P. and Makepeace, A.J. (compilers), 2001. Bedrock Geology, Yukon Territory. Geological Survey of Canada Open File 3754 and Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Open File 2001-1, 1:1 000 000 scale.

Hills, L.V. and Braman, D.R., 1978. Sedimentary structures of the Imperial Formation, Northwest Canada. *In:* Display Summaries, A.F. Embry (compiler), Canadian Society of Petroleum Geologists, p. 35-37.

Levorson , A.I., 2001. Geology of Petroleum, (2nd edition). AAPG Foundation, Oklahoma, p. 97-143.

Lutchman, M., 1977. Mississippian clastic wedge. *In:* Lower Mackenzie Energy Corridor Study, Geological Component. AGAT Consultants Ltd., p. M1-M10.

Morrow, D.W., 1999. Lower Paleozoic stratigraphy of northern Yukon Territory and northwestern District of Mackenzie. Geological Survey of Canada, Bulletin 538, 202 p.

Morrow, D.W., Jones, A.L. and Dixon, J., 2006. Infrastructure and Resources of the Northern Canadian Mainland Sedimentary Basin. Geological Survey of Canada, Open File 5152, 59 p.

Neuendorf, K.K.E., Mehl, J.P. Jr. and Jackson, J.A. (eds), 2005. Glossary of Geology, Fifth Edition. American Geological Institute, Alexandria, Virginia, 779 p.

Norris, A.W., 1968. Reconnaissance Devonian stratigraphy of Northern Yukon Territory and Northwestern District of Mackenzie. Geological Survey of Canada, Paper 67-53, 74 p.

Norris, A.W., 1985. Stratigraphy of Devonian outcrop belts in northern Yukon Territory and northwestern District of Mackenzie (operation Porcupine area). Geological Survey of Canada, Memoir 410, 81 p.

Norris, A.W., 1997. Devonian. *In:* The Geology, Mineral and Hydrocarbon Potential of Northern Yukon Territory and Northwestern District of Mackenzie, D.K. Norris (ed.), Geological Survey of Canada, Bulletin 422, p. 163-200.

Norris, D.K., 1981. Geology: Trail River, Yukon-Northwest Territories. Geological Survey of Canada, Map 1524A, 1:250 000 scale.

Norris, D.K., 1982a. Geology: Snake River, Yukon-Northwest Territories. Geological Survey of Canada, Map 1529A, 1:250 000 scale.

Norris, D.K., 1982b. Geology: Wind River, Yukon-Northwest Territories. Geological Survey of Canada, Map 1528A, 1:250 000 scale.

Norris, D.K. 1984. Geology of the northern Yukon and northwestern District of Mackenzie. Geological Survey of Canada, Map 1581A, 1:500 000 scale.

Norris, D.K. (ed.), 1997. Geology and mineral and hydrocarbon potential of Northern Yukon Territory and Northwestern District of Mackenzie. Geological Survey of Canada, Bulletin 422, 401 p.

Osadetz, K.G., MacLean, B.C., Morrow, D.W., Dixon, J. and Hannigan, P.K., 2005. Petroleum Resource Assessment, Peel Plateau and Plain, Yukon Territory, Canada. Yukon Geological Survey, Open File 2005-3, Geological Survey of Canada, Open File 4841, 76 p.

Peters, K.E., 1986. Guidelines for evaluating petroleum source rock using programmed pyrolysis. American Association of Petroleum Geologists Bulletin, vol. 70, no. 3, p. 318-329.

Peters, K.E., Walters, C.C. and Moldowan, J.M., 2005. The Biomarker Guide, Volume 1. Biomarkers and Isotopes in the Environment and Human History. Cambridge University Press, New York, 471 p.

Pigage, L., 2007. Yukon Stratigraphic Correlation Chart, v. 3.0. Yukon Geological Survey and Oil and Gas Management Branch, YGS Open File 2007-2.

Pyle, L.J., Jones, A.L. and Gal, L.P., 2006. Geoscience Knowledge Synthesis: Peel Plateau and Plain, a prospective hydrocarbon province in the Northern Mackenzie Corridor. Geological Survey of Canada, Open File 5234, 85 p.

Pugh, D.C., 1983. Pre-Mesozoic geology in the subsurface of Peel River map area, Yukon Territory and District of Mackenzie. Geological Survey of Canada, Memoir 401, 61 p.

Richards, B.C., Bamber, E.W. and Utting. J., 1997. Upper Devonian to Permian. *In:* The Geology, Mineral and Hydrocarbon Potential of Northern Yukon Territory and Northwestern District of Mackenzie, D.K. Norris (ed.), Geological Survey of Canada, Bulletin 422, p. 201-251.

Shell Canada Ltd., 1964. Report on 1964 Surface Mapping Completed in Yukon and Northwest Territories. National Energy Board report 037-01-06-00060.

Staplin, F.L., 1969. Sedimentary organic matter, organic metamorphism, and oil and gas occurrence. Canadian Petroleum Geologists Bulletin 17, p. 47-66.

Tassonyi, E.J., 1969. Subsurface geology, lower Mackenzie River and Anderson River area, District of Mackenzie. Geological Survey of Canada, Paper 68-25, 207 p.

APPENDIX 1: Rock-Eval/TOC data

													NAD83, Zone 8	
Sample	Formation	T_{max} (°C)	VR	TAI	S1	S2	S3	PI	S2/S3	TOC	HI	OI	UTME	UTMN
06TNT-TR-001A	Canol	610			0.02	0.04	0.42	0.31	0.10	5.33	1	8	478123	7366448
06TNT-TR-002	Canol	609			0.01	0.06	0.50	0.21	0.12	4.06	1	12	478147	7366501
06TNT-TR-003	Canol	424	1.8		0.02	0.02	0.78	0.40	0.03	3.75	1	21	478153	7366536
06TNT-TR-004	Canol	488			0.01	0.06	0.65	0.17	0.09	4.39	1	15	478147	7366501
06TNT-TR-024B	Canol	610			0.01	0.05	0.42	0.17	0.12	3.70	1	11	477802	7366192
06TNT-TR-024C	Canol	610			0.02	0.08	0.28	0.20	0.29	5.05	2	6	477802	7366192
06TNT-TR-024E	Canol	609			0.01	0.12	0.31	0.09	0.39	5.63	2	6	477887	7366189
06TNT-TR-024G	Canol	609			0.01	0.03	0.39	0.26	0.08	3.34	1	12	477989	7366393
06TNT-TR-024I	Canol	609			0.01	0.16	1.13	0.06	0.14	6.19	3	18	478054	7366379
06TNT-TR-024K	Canol	610	1.81		0.03	0.10	0.33	0.26	0.30	6.25	2	5	478119	7366453
07TNT-RR-14A	Canol	422			0.01	0.03	0.16	0.24	0.19	0.20	15	80	475322	7385986
07TNT-RR-14B	Canol	607			0.02	0.06	1.62	0.24	0.04	2.41	2	67	475322	7385986
07TNT-SR-40A	Canol	608			0.01	0.06	0.53	0.19	0.11	4.94	1	11	551078	7270060
07TNT-SR-40B	Canol	607			0.02	0.09	0.25	0.20	0.36	6.92	1	4	572154	7267463
07TNT-SR-41A	Canol	607			0.02	0.05	0.18	0.23	0.28	3.08	2	6	571692	7270748
07TNT-SR-41B	Canol	607			0.01	0.03	0.19	0.23	0.16	3.16	1	6	571679	7270744
07TNT-SR-41C	Canol	607			0.02	0.05	0.24	0.24	0.21	3.18	2	8	571679	7270744
07TNT-SR-41D	Canol/ Imperial?	607			0.01	0.04	0.13	0.13	0.31	1.39	3	9	571634	7270745
07TNT-SR-41F	Canol/ Imperial?	607			0.01	0.04	0.15	0.16	0.27	1.87	2	8	571634	7270745
06TNT-TR-007	Imperial	594			0.01	0.07	0.35	0.07	0.20	0.76	9	46	478543	7366649
06TNT-TR-008	Imperial	324			0.13	0.18	1.58	0.43	0.11	6.41	3	25	478489	7366667
06TNT-TR-009	Imperial	606			0.01	0.06	0.27	0.11	0.22	1.11	5	24	478545	7366689
06TNT-TR-010	Imperial	602			0.00	0.05	0.17	0.03	0.29	0.73	7	23	478605	7366713
06TNT-TR-011	Imperial	428		3+/4-	0.02	0.04	0.88	0.37	0.05	6.98	1	13	478711	7366788
06TNT-TR-012A	Imperial	607		3+/4-	0.02	0.44	0.46	0.04	0.96	7.03	6	7	481330	7370081
06TNT-TR-012D	Imperial	546			0.00	0.11	0.20	0.04	0.55	0.62	18	32	481404	7370113
06TNT-TR-012F	Imperial	555		3+/4-	0.00	0.12	0.78	0.03	0.15	0.77	16	101	481439	7370117
06TNT-TR-013A	Imperial	540		3+/4-	0.01	0.16	0.35	0.07	0.46	0.80	20	44	481618	7370239
06TNT-TR-013B	Imperial	554	1.58		0.01	0.14	0.49	0.04	0.29	0.73	19	67	481469	7370231
06TNT-TR-013E	Imperial	540			0.01	0.13	0.17	0.05	0.76	0.64	20	27	481778	7370230
06TNT-TR-013F	Imperial	539		3+/4-	0.00	0.06	0.08	0.06	0.75	0.33	18	24	481790	7370212
06TNT-PR-032A	Imperial	480			0.05	0.31	1.44	0.15	0.22	0.99	31	145	515914	7315451
06TNT-PR-032B	Imperial	431	0.7		2.48	2.93	0.23	0.46	12.74	3.94	74	6	515914	7315451
06TNT-PR-032C	Imperial	438			1.06	2.82	0.30	0.27	9.40	5.07	56	6	515914	7315451
06TNT-PR-035A	Imperial	443		2	1.78	6.20	0.14	0.22	44.29	4.22	147	3	518634	7317560
07TNT-TR-01C	Imperial	494			0.03	0.39	0.27	0.07	1.44	1.03	38	26	482781	7370653
07TNT-TR-01D	Imperial	496			0.02	0.44	0.26	0.04	1.69	1.22	36	21	482807	7370647
07TNT-TR-01E	Imperial	485			0.02	0.24	0.20	0.07	1.20	0.57	42	35	482922	7370654
07TNT-TR-02B	Imperial	602			0.01	0.07	0.24	0.09	0.29	0.99	7	24	479871	7368934
07TNT-RR-15A	Imperial	577			0.00	0.09	0.15	0.04	0.60	0.75	12	20	480166	7387921
07TNT-TET-22A	Imperial	581			0.01	0.10	0.17	0.06	0.59	0.86	12	20	477777	7399240
07TNT-TET-23A	Imperial	605			0.00	0.02	0.23	0.12	0.09	0.57	4	40	472740	7400219
07TNT-TR-33A	Imperial	484			0.01	0.33	0.14	0.04	2.36	0.77	43	18	492785	7379035
07TNT-TR-33C	Imperial	483			0.01	0.22	0.30	0.04	0.73	0.72	31	42	483012	7370833

Appendix 1 continued

													NAD83, Zone 8	
Sample	**Formation**	**T_{max} (°C)**	**VR**	**TAI**	**S1**	**S2**	**S3**	**PI**	**S2/S3**	**TOC**	**HI**	**OI**	**UTME**	**UTMN**
07TNT-SRT-42A	Imperial	608			0.01	0.06	0.24	0.16	0.25	4.86	1	5	571448	7275031
07TNT-SRT-42B	Imperial	607			0.01	0.06	0.35	0.12	0.17	5.47	1	6	571441	7275024
06TNT-TR-014A	Tuttle	451		2	0.05	0.36	0.43	0.13	0.84	0.62	58	69	483250	7371104
06TNT-TR-014C	Tuttle	447			0.02	0.30	0.13	0.06	2.31	0.67	45	19	483250	7371104
06TNT-TR-014G	Tuttle	451		2	0.19	4.84	0.36	0.04	13.44	4.22	115	9	483250	7371104
06TNT-TR-015J	Tuttle	457			0.02	0.56	0.31	0.03	1.81	1.00	56	31	483445	7371302
06TNT-TR-015K	Tuttle	451			0.01	0.21	0.30	0.02	0.70	0.28	75	107	483479	7371292
06TNT-TR-016A	Tuttle	435		2	0.45	20.57	0.26	0.02	79.12	6.42	320	4	483552	7371310
06TNT-TR-016C	Tuttle	437			0.07	3.51	0.21	0.02	16.71	2.59	136	8	483552	7371310
06TNT-TR-016-2	Tuttle	434	0.61		0.05	2.05	0.55	0.02	3.73	2.29	90	24	483570	7371318
06TNT-TR-017A	Tuttle	437		2	0.10	1.93	0.45	0.05	4.29	1.98	97	23	484937	7372301
06TNT-TR-017C	Tuttle	432			0.07	2.52	0.26	0.03	9.69	1.80	140	14	484937	7372301
06TNT-TR-019E	Tuttle	430	0.61	2	0.10	10.71	3.62	0.01	2.96	10.37	103	35	483971	7391104
06TNT-RR-191	Tuttle	451			0.04	0.89	0.53	0.05	1.68	2.86	31	19	483971	7391104
06TNT-RR-019K	Tuttle	434		2	0.01	1.57	0.50	0.01	3.14	2.03	77	25	483995	7391125
06TNT-RR-020A	Tuttle	430		2	0.04	2.22	0.15	0.02	14.80	2.33	95	6	484113	7391184
06TNT-RR-020B	Tuttle	424			0.09	1.45	0.49	0.06	2.96	2.92	50	17	484090	73911172
06TNT-RR-020C	Tuttle	423		2	0.06	1.00	0.19	0.06	5.26	1.94	52	10	484090	73911172
06TNT-RR-020F	Tuttle	430			0.04	2.14	0.10	0.02	21.40	1.54	139	6	484066	7391159
06TNT-RR-020H	Tuttle	425		2	0.91	64.15	7.92	0.01	8.10	29.30	219	27	484059	7391144
06TNT-RR-020H	Tuttle	424		2	0.73	66.60	7.85	0.01	8.48	40.25	165	20	484059	7391144
06TNT-RR-020M	Tuttle	427			0.11	1.21	1.86	0.09	0.65	3.35	36	56	484061	7391137
06TNT-RR-020O	Tuttle	426			0.28	24.07	16.90	0.01	1.42	26.18	92	65	484061	7391137
06TNT-RR-020O	Tuttle	429	0.65		0.27	26.49	14.05	0.01	1.89	37.40	71	38	484061	7391137
06TNT-RR-020S	Tuttle	437			0.08	0.73	0.28	0.10	2.61	1.46	50	19	484055	7391159
06TNT-RR-020V	Tuttle	428		2	0.02	1.45	0.49	0.02	2.96	1.92	76	26	484041	7391150
06TNT-RR-028A	Tuttle?	440		2	0.02	0.49	0.25	0.03	1.96	0.77	64	32	485951	7391245
06TNT-TR-029A	Tuttle	425	0.51		0.05	0.81	0.16	0.06	5.06	1.37	59	12	490861	7369955
06TNT-TR-029C	Tuttle	425		2	0.17	8.55	0.24	0.02	35.63	3.60	238	7	490861	7369955
06TNT-TR-030A	Tuttle	409			4.03	3.57	0.14	0.53	25.50	0.95	376	15	494000	7372110
07TNT-TR-01H	Tuttle	449			0.10	0.32	0.18	0.23	1.78	0.54	59	33	483303	7370860
07TNT-TR-01I	Tuttle	451			0.08	0.35	0.32	0.20	1.09	0.74	47	43	483303	7370860
07TNT-TR-03A	Tuttle	403			6.73	5.63	0.09	0.54	62.56	1.48	380	6	492479	7371153
07TNT-TR-03E	Tuttle	437			0.02	0.92	0.56	0.02	1.64	1.71	54	33	492374	7371087
07TNT-TR-03F	Tuttle	434			0.01	0.52	0.37	0.02	1.41	0.90	58	41	492374	7371087
07TNT-TR-05D	Tuttle	412			6.39	6.38	0.09	0.50	70.89	1.44	443	6	494063	7372007
07TNT-TR-05F	Tuttle	419			1.88	2.84	0.17	0.40	16.71	0.62	458	27	494049	7371914
07TNT-TR-05H	Tuttle	427			0.08	6.91	0.36	0.01	19.19	4.09	169	9	493706	7371672
07TNT-TR-05J	Tuttle	410			6.80	7.06	0.11	0.49	64.18	1.55	455	7	493706	7371672
07TNT-TR-06C	Tuttle/ Cretaceous?	433			0.05	1.78	0.33	0.02	5.39	1.28	139	26	494382	7372458
07TNT-RR-16A	Tuttle? Cf?	426			0.12	2.06	0.11	0.06	18.73	2.26	91	5	484649	7391140
07TNT-NTR-20A	Tuttle	427			0.03	2.09	0.12	0.02	17.42	1.34	156	9	479769	7404483
07TNT-NTR-20B	Tuttle	428			0.15	5.05	0.70	0.03	7.21	2.09	242	33	479713	7404507
07TNT-TET-21A	Tuttle	437			0.06	1.21	0.20	0.05	6.05	1.31	92	15	482352	7400500

Appendix 1 continued

													NAD83, Zone 8	
Sample	Formation	T_{max} (°C)	VR	TAI	S1	S2	S3	PI	S2/S3	TOC	HI	OI	UTME	UTMN
07TNT-TET-21B	Tuttle	447			0.04	1.29	0.18	0.03	7.17	1.29	100	14	482286	7400408
07TNT-MOR-39A	Mo	443			0.14	2.84	0.15	0.05	18.93	2.10	135	7	546139	7350603
07TNT-SR-43A	Mo	468			0.08	2.13	0.39	0.04	5.46	4.21	51	9	571857	7279283
07TNT-SR-43B	Mo	470			0.10	1.43	0.24	0.06	5.96	2.38	60	10	571852	7279389
07TNT-MOR-46C	Mo	451			0.11	1.89	0.95	0.06	1.99	2.86	66	33	553978	7270171
07TNT-MOR-46F	Mo	454			0.36	2.61	1.32	0.12	1.98	3.93	66	34	554160	7270376
07TNT-SR-47E	Mo	470			0.15	3.79	0.34	0.04	11.15	5.22	73	7	571857	7279365
07TNT-SR-47H	Mo	469			0.10	1.49	0.36	0.06	4.14	2.69	55	13	571852	7279389
07TNT-SR-47I	Mo	464			0.16	14.72	1.11	0.01	13.26	11.31	130	10	571855	7279532
07TNT-SR-47L	Mo	473			0.24	1.78	1.34	0.12	1.33	3.93	45	34	571840	7279585
07TNT-SR-47M	Mo	476			0.26	1.75	0.76	0.13	2.30	3.36	52	23	571843	7279614
07TNT-MO-50A	Mo	480			0.10	1.54	0.71	0.06	2.17	3.89	40	18	581624	7270239
06TNT-CC-026B	Cf	443			0.48	5.30	0.08	0.08	66.25	2.54	209	3	523198	7325395
06TNT-CC-026C	Cf	444			2.37	11.37	0.19	0.17	59.84	4.04	281	5	523163	7325414
06TNT-CC-026D	Cf	441			2.18	9.87	0.12	0.18	82.25	3.47	284	3	523163	7325414
06TNT-CC-026E	Cf	441			2.27	8.08	0.13	0.22	62.15	3.10	261	4	523225	7325515
06TNT-CC-026G	Cf	436			1.42	31.45	0.64	0.04	49.14	12.17	258	5	523295	7325620
06TNT-CC-026I	Cf	437			0.01	0.05	0.24	0.17	0.21	0.07	71	343	523167	7325671
06TNT-CC-026J	Cf	440	0.65		1.47	21.18	0.64	0.06	33.09	9.24	229	7	523167	7325671
06TNT-CC-026K	Cf	443		2	1.59	21.03	0.36	0.07	58.42	8.64	243	4	523167	7325671
06TNT-PR-033A	Cf	497		2	0.27	1.56	0.28	0.15	5.57	4.54	34	6	529110	7314150
06TNT-PR-033B	Cf	574	0.78		0.10	1.03	0.50	0.09	2.06	3.89	26	13	529110	7314150
06TNT-PR-033C	Cf	354			0.01	0.05	0.15	0.18	0.33	0.03	167	500	529110	7314150
07TNT-TR-04A	Cf	432			0.05	1.60	0.20	0.03	8.00	1.46	110	14	487862	7371005
07TNT-CR-12A	Cf	439			0.79	8.87	0.13	0.08	68.23	3.51	253	4	507992	7344887
07TNT-CC-27A	Cf	438			0.46	10.27	0.36	0.04	28.53	6.10	168	6	526761	7327329
07TNT-TT-32A	Cf	432			0.10	1.69	0.85	0.06	1.99	1.48	114	57	492785	7379035
07TNT-ACH-34A	Cf	441			2.51	12.79	0.12	0.16	106.58	4.46	287	3	512804	7328585
07TNT-ACH-34B	Cf	438			3.89	10.38	0.17	0.27	61.06	3.73	278	5	512907	7328592
07TNT-ACH-34B	Cf	444			5.07	10.74	0.13	0.32	82.62	3.29	326	4	512907	7328592
07TNT-ACH-34C	Cf	437			1.12	8.13	0.14	0.12	58.07	3.11	261	5	512907	7328592
06TNT-CR-031A	unnamed shale	431		2	0.10	4.52	0.37	0.02	12.22	3.07	147	12	512994	7344407
06TNT-CR-031C	unnamed shale	433	0.67		0.65	16.21	0.29	0.04	55.90	8.69	187	3	512994	7344407
07TNT-TR-10A	unnamed shale	438			0.06	0.72	0.37	0.08	1.95	1.19	61	31	496967	7347199
07TNT-CR-11A	unnamed shale	436			0.09	3.30	0.20	0.03	16.50	2.13	155	9	501997	7347100
07TNT-CR-11B	unnamed shale	431			0.98	33.99	0.97	0.03	35.04	12.43	273	8	501997	7347100