Geological Survey of Canada

CURRENT RESEARCH
2006-A6

2005 reconnaissance field program in Peel Plateau and Peel Plain region, Northwest Territories and Yukon Territory

L.J. Pyle, A.L. Jones, L.P. Gal, J.G. Abbott, A.D. McCracken, M.G. Fowler, and L.D. Stasiuk

2006

CURRENT RESEARCH

Natural Resources Canada Ressources naturelles Canada

Canada

ISSN 1701-4387
Catalogue No. M44-2006/A6E-PDF
ISBN 0-662-43400-5

A copy of this publication is also available for reference by depository libraries across Canada through access to the Depository Services Program's Web site at http://dsp-psd.pwgsc.gc.ca

A free digital download of this publication is available from GeoPub: http://geopub.nrcan.gc.ca/index_e.php

Toll-free (Canada and U.S.A.): 1-888-252-4301

Critical reviewer
Yvon Lemieux

Authors' addresses

L.J. Pyle (lpyle@nrcan.gc.ca)
GSC Pacific (Sidney),
9860 West Saanich Road,
Sidney, British Columbia V8L 3S1

J.G. Abbott (grant.abbott@gov.yk.ca)
Yukon Geological Survey,
P.O. Box 2703 (K-10),
Whitehorse, Yukon Territory Y1A 2C6

A.L. Jones (Adrienne_Jones@gov.nt.ca)
L.P. Gal (Len_Gal@gov.nt.ca)
Northwest Territories Geoscience Office,
P.O. Box 1500,
Yellowknife, Northwest Territories X1A 2R3

A.D. McCracken (Sandy.McCracken@nrcan.gc.ca)
M.G. Fowler (mfowler@nrcan.gc.ca)
L.D. Stasiuk (lstasiuk@nrcan.gc.ca)
GSC Calgary,
3303-33 Street NW,
Calgary, Alberta T2L 2A7

Publication approved by GSC Pacific

Original manuscript submitted: 2006-02-20
Final version approved for publication: 2006-03-01

Correction date:

2005 reconnaissance field program in Peel Plateau and Peel Plain region, Northwest Territories and Yukon Territory

L.J. Pyle, A.L. Jones, L.P. Gal, J.G. Abbott, A.D. McCracken, M.G. Fowler, and L.D. Stasiuk

Pyle, L.J., Jones, A.L., Gal, L.P., Abbott, J.G., McCracken, A.D., Fowler, M.G., and Stasiuk, L.D., 2006: 2005 reconnaissance field program in Peel Plateau and Peel Plain region, Northwest Territories and Yukon Territory; Geological Survey of Canada, Current Research 2006-A6, 13 p.

Abstract: In 2005, reconnaissance fieldwork was carried out in Peel Plateau and Peel Plain (Peel region) which lies along the northern Mackenzie corridor. Peel region is a prospective petroleum province that straddles the Northwest Territories–Yukon Territory border, and the focus of a four-year, multi-agency study. Reconnaissance on the regional geology and petroleum potential included surveying river exposures in Peel region and along the deformation front that flanks the western and southern edges of Peel Plateau (Richardson and Mackenzie mountains, respectively) within Trail River (NTS 106 L), Snake River (NTS 106 F), Ramparts River (NTS 106 G), and Sans Sault Rapids (NTS 106 H) map areas. Rock-Eval® pyrolysis for TOC of potential source-rock horizons indicates excellent original source-rock potential of the Canol and Hare Indian formations. Conodont samples provide new biostratigraphic ages for Ordovician to Devonian strata. Conodont colour alteration index values range from 2 to 5.

Résumé : En 2005, nous avons mené des travaux de reconnaissance dans le plateau de Peel et la plaine de Peel (région de Peel), le long de la partie septentrionale du corridor du Mackenzie. La région de Peel est une province pétrolière prometteuse qui chevauche la limite entre les Territoires du Nord-Ouest et le Territoire du Yukon et fait l'objet d'une étude quadriennale multi-agences. Les travaux de reconnaissance sur la géologie régionale et le potentiel pétrolier comprennaient l'examen d'affleurements le long de cours d'eau dans la région de Peel et le long du front de déformation qui borde les marges ouest et sud du plateau de Peel (respectivement les monts Richardson et Mackenzie) à l'intérieur des régions cartographiques de la rivière Trail (SNRC 106 L), de la rivière Snake (SNRC 106 F), de la rivière Ramparts (SNRC 106 G) et des rapides Sans Sault (SNRC 106 H). La pyrolyse Rock-Eval® pour déterminer les matières organiques totales d'éventuels horizons de roche mère révèle un excellent potentiel dans les formations de Canol et de Hare Indian. Des échantillons de conodontes fournissent de nouveaux âges biostratigraphiques pour les strates s'échelonnant de l'Ordovicien au Dévonien. Les valeurs de l'indice d'altération de la couleur des conodontes varient de 2 à 5.

INTRODUCTION

The project 'Regional Geoscience Studies and Petroleum Potential, Peel Plateau and Plain, Northwest Territories and Yukon' is a multidisciplinary, four-year (2005–2009), collaborative study by the Geological Survey of Canada (GSC), Northwest Territories Geoscience Office (NTGO), and Yukon Geological Survey (YGS). Peel Plateau and Peel Plain (Peel region, Fig. 1) was identified by industry-sector clients as a high priority exploration area of the Northern Canadian mainland sedimentary basin at a NTGO needs assessment workshop in 2004. Peel region has widespread hydrocarbon potential, but is underexplored and its geological history is poorly understood. Much of the bedrock mapping and exploration drilling in the area dates back to the 1960s. The project aligns with the outcomes of Natural Resources Canada's 'Northern Energy Development Program', by addressing the need for improved geological information in this prospective petroleum province.

The main activities of the 'Regional Geoscience Studies and Petroleum Potential, Peel Plateau and Plain, Northwest Territories and Yukon' include field research to expand geoscience data and knowledge through thematic studies (stratigraphy, sedimentology, paleontology, structure, and organic geochemistry), and compilation of new data for energy-resource assessments. Subsurface data come from more than 70 wells in this area (Fig. 1). Outcrop is restricted mainly to river cuts in the Peel Plain, but is well exposed in the Cordilleran deformation front that flanks the western and southern edges of Peel Plateau (Richardson and Mackenzie mountains, respectively).

Eleven 1:250 000 scale GSC bedrock geology maps cover Peel region (Fig. 2).

Reconnaissance fieldwork focused first on exposures along the Dempster Highway that transects the northwest corner of Peel region through Arctic Red River (NTS 106 N), Fort McPherson (NTS 106 M), Bell River (NTS 116 P), and Eagle River (NTS 116-I) map areas. The second phase of reconnaissance focused on sections in Trail River (NTS 106 L), Snake River (NTS 106 F), Ramparts River (NTS 106 G), and Sans Sault Rapids (NTS 106 H) map areas (Fig. 2). The purpose of this report is to 1) highlight the regional geological framework observed during the 2005 reconnaissance survey, and 2) report results of reconnaissance sampling (Rock-Eval pyrolysis for TOC, preliminary age determinations based on conodonts, and conodont colour alteration indices).

STUDY AREA LOCATION AND PHYSIOGRAPHY

Peel region is a prospective hydrocarbon exploration area that forms part of the Interior Plains (Bostock, 1970). Peel region lies between 65°N and 68°N latitude, bounded to the south by the Mackenzie Mountains, to the north by the Mackenzie Delta, and eastward by Anderson Plain. The study area extends southwest from Mackenzie River (128°W) to the deformation front in the Richardson Mountains, which forms its western limit (136°W; Fig. 1). Peel Plain consists of lowlands with elevations of 150–450 m; Peel Plateau is an erosional remnant with Cretaceous sandstone terraces up to 950 m in elevation (Stott and Klassen, 1993). Outcrop is limited in Peel region, with exposure mainly along creeks and rivers and some outcrops of Devonian rocks in river and lake valleys west of Mackenzie River (Aitken et al., 1969). Deformed strata of the northern Canadian Cordillera (Mackenzie and Richardson mountains) are contiguous with units of Peel region and offer the best exposure for study. The Mackenzie Mountains rise to elevations of more than 1800 m; the Richardson Mountains have a maximum elevation of 1350 m (Morrow, 1999).

OVERVIEW OF RECONNAISSANCE

The reconnaissance field survey was carried out in two phases. Geology of Peel region was first examined along the existing infrastructure of the Dempster Highway and then by helicopter to reach remote river exposures and ridge sections of the Richardson Mountains and northern Mackenzie Mountains.

Dempster Highway

The Dempster Highway from Inuvik, Northwest Territories to Eagle Plains, Yukon Territory transects the northwest corner of Peel region and exposes strata that span from Proterozoic to Quaternary. Geology of 25 stops was documented in order to update data for an out-of-print roadside geological guide (Norris et al., 1992) for the Dempster Highway (Fig. 3), but details are not presented in this report. The guide is an outreach initiative and will include updated photographs, illustrations, and descriptions of geological stops to highlight the geology, landscape features, and natural resources along the 745 km route from Inuvik to the junction with the Klondike Highway located 45 km east of Dawson City, Yukon Territory.

Peel region and adjacent Cordillera

Reconnaissance also focused on strata of the Richardson and Mackenzie mountains. In total, 16 stratigraphic sections, including six type sections (Table 1) were examined in Trail River (106 L), Snake River (106 F), Ramparts River (106 G), and Sans Sault Rapids (106 H) map areas. More than 70 wells in Peel region (Fig. 1, 3) have been drilled through Phanerozoic strata that lie unconformably on Proterozoic siliciclastic rocks. This subsurface record is correlative with deformed strata in outcrop along the eastern flank of the Richardson Mountains and northern front of the Mackenzie Mountains

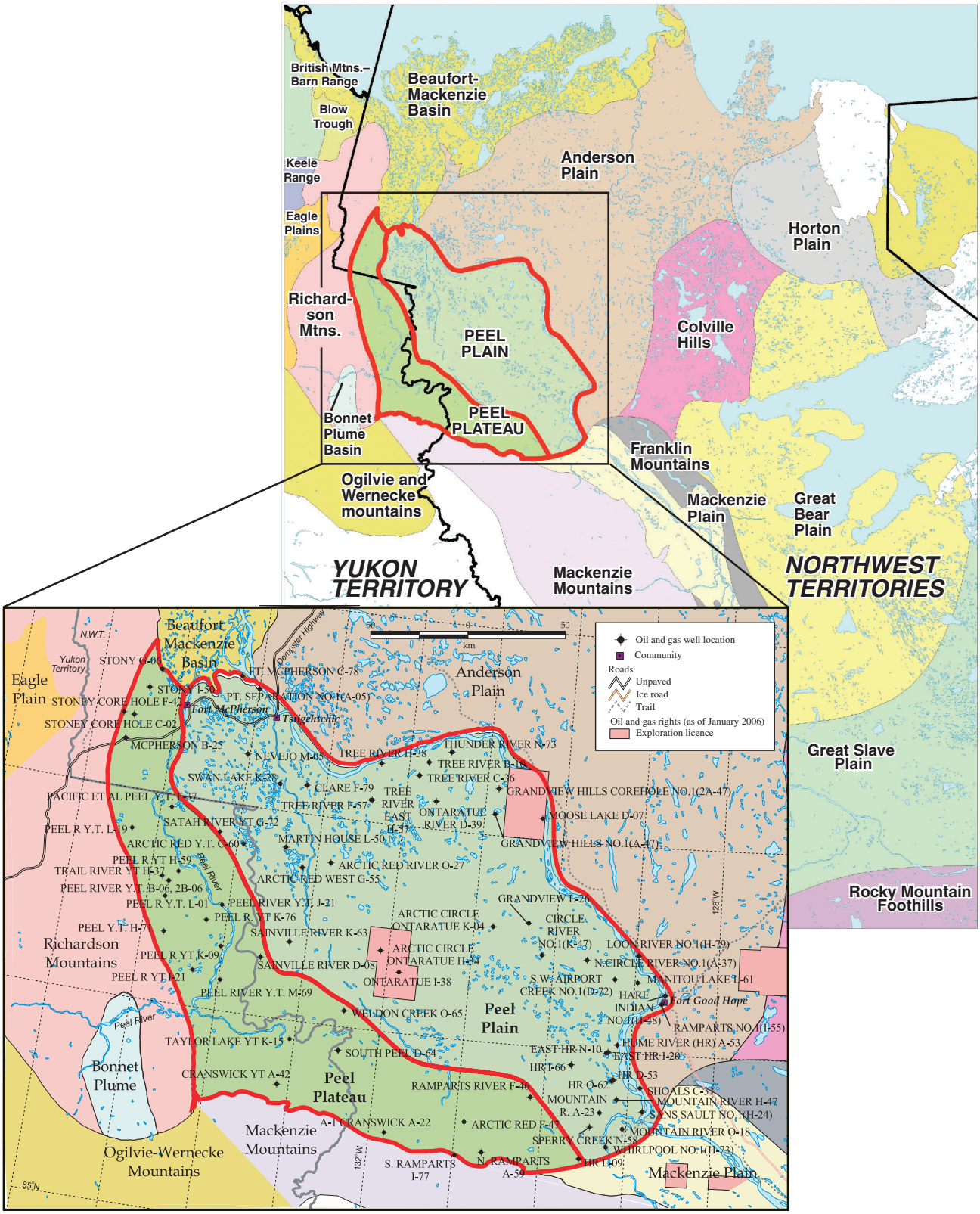

Figure 1. Location map showing the petroleum regions of Northwest Territories and Yukon Territory (*modified from* Mossop, 2004) with detail of Peel Plateau and Peel Plain and locations of exploratory petroleum wells (Mossop et al., 2004).

Figure 2. Geological Survey of Canada map coverage of Peel region (scale 1:250 000).

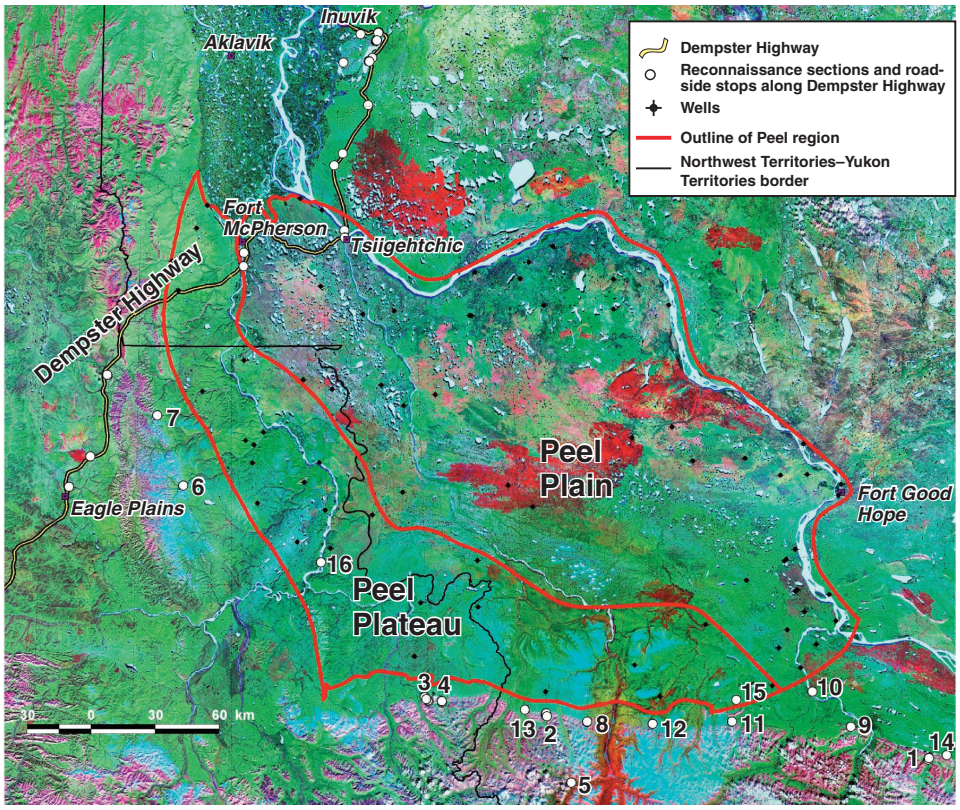

Figure 3. Landsat image of Peel region showing reconnaissance sections (Table 1) and key stops along the Dempster Highway.

(Fig. 4). The cumulative thickness of the total supracrustal wedge across the Peel region ranges from a zero-edge at the Canadian Shield to the east to 7 km where the Interior Platform meets the Cordillera, and up to 20 km within the orogen (Norris, 1985). Norris (1996) divided the stratigraphic record into six tectonostratigraphic assemblages: Werneckian (1700–1200 Ma), Inuvikian (1200–800 Ma), Rapitanian (800–543 Ma), Franklinian (543–360 Ma), Ellesmerian (360–130 Ma), and Brookian (130–45 Ma), which includes the Columbian (130–70 Ma) and Laramidian (70–45 Ma) assemblages. More details on the Peel region can be found in a synthesis by Pyle et al. (2006).

Proterozoic

There are no surface outcrops of Proterozoic rocks in Peel region, but seismic records indicate five unconformity-bounded sequences that are correlated provisionally with the

Table 1. Summary of sections examined during the reconnaissance program.

Section name (NTS)	Location	Description
1. Imperial Canyon (106 H)	65°05.972′, 128°03.644′	Canyon section: location is base of Mt. Cap Fm; Saline River, Franklin Mtn., Mt. Kindle and Devonian succession exposed through canyon; base of Franklin Mtn. at 65°06.547′, 128°01.891′.
2. Morrow section 27 (106 G)	65°24.060′, 131°49.035′	Ridge section: location is unconformable contact of Katherine Gp and Franklin Mtn. formation; ridge exposes Mt. Kindle, Delorme Gp, Arnica, and Landry formations
3. Near Morrow section 41, type section of Mt. Baird Fm (106 F)	65°29.758′, 133°00.293′	Ridge section: location near contact of Mt. Kindle and Delorme Gp; Katherine Gp and Franklin Mtn. Fm form ridge to east; northward down nose of ridge at 65°30′30″, 133°03′ is repetition of Delorme Gp, overlain by Arnica and Landry formations and shelf-edge transition facies of Mount Baird Fm (type section).
4. Near Morrow section 44 (106 F)	65°29.488′, 132°52.126′	Ridge section: location on Franklin Mtn. Fm; section spans from Katherine Gp, through Ronning and Delorme groups. Arnica and Landry formations; Morrow (1999) section 44 east at 65°29′37″, 132°46.20″.
5. Reconnaissance flight (106 G)	65°07.728′, 131°36.389′	Ridge section: location on transitional Mt. Kindle Fm, forms part of section 2 of Cecile et al. (1982).
6. Trail River (106 L)	66°24.810′, 135°30.243′	Creek section: location is ?Loucheux formation of Road River Group; base of section 57 of Morrow (1999) lies at top of Rabbitkettle Fm at 66°24′44″, 135°28′36″.
7. Tetlit Creek, type section of Road River Fm (106 L)	66°42.465′, 135°47.275′	Creek section: location is base of Road River type section, section 58 of Morrow (1999), section 4 of Cecile et al. (1982)
8. Rumbly Creek (106 G)	65°22.746′, 131°25.025′	Ridge section: location in Arnica Fm, overlain by Landry Fm.
9. Powell Creek, type section of Canol Fm (106 H)	65°16.373′, 128°46.513′	Creek section: location in Bear Rock Fm at front of northern Mackenzie Mountains; section extends southwest along creek through Mt. Kindle, Franklin Mtn., and Saline River formations to Katherine Gp. Northward, Hume, Hare Indian, Ramparts, Canol, and Imperial formations are exposed.
10. Mountain River (106 H)	65°26.113′, 129°07.730′	Cliff section: location at Hare Indian–Ramparts contact on west cliff-face, northern limb of Imperial anticline; underlain by Hume Fm and Bear Rock Fm in core of anticline.
11. Type section of Hume Fm (106 H)	65°20.360′, 129°57.590′	Creek section: location on east branch of Hume River at Hume–Hare Indian contact; Canol Fm overlies Hare Indian Fm.
12. East of Arctic Red (106 G)	65°21.257′, 130°45.521′	Creek section: location on undifferentiated Hare Indian–Canol Fm, overlain by Imperial Fm (section 1 of Norris (1968).
13. Flyaway Creek (106 F)	65°26.710′, 132°02.053′	Creek section: location at top of Hume Fm, near Hume-Canol contact. Northward, Imperial Fm overlies Canol Fm and southward, Landry, Arnica, and Delorme groups underlie Hume Fm.
14. Type section of Imperial Fm, Imperial River (96 E)	65°06.663′, 127°51.001′	Creek section: location in upper part of type section of Imperial Fm.
15. East of Hume River (106 H)	65°25.732′, 129°53.969′	Creek exposure: location in upper Arctic Red Fm.
16. Peel River, type sections of Martin House and Arctic Red formations (106 L)	66°05.359′, 134°04.383′	River section: location near contact of Martin House and Arctic Red formations (section 1 of Mountjoy and Chamney (1969)).

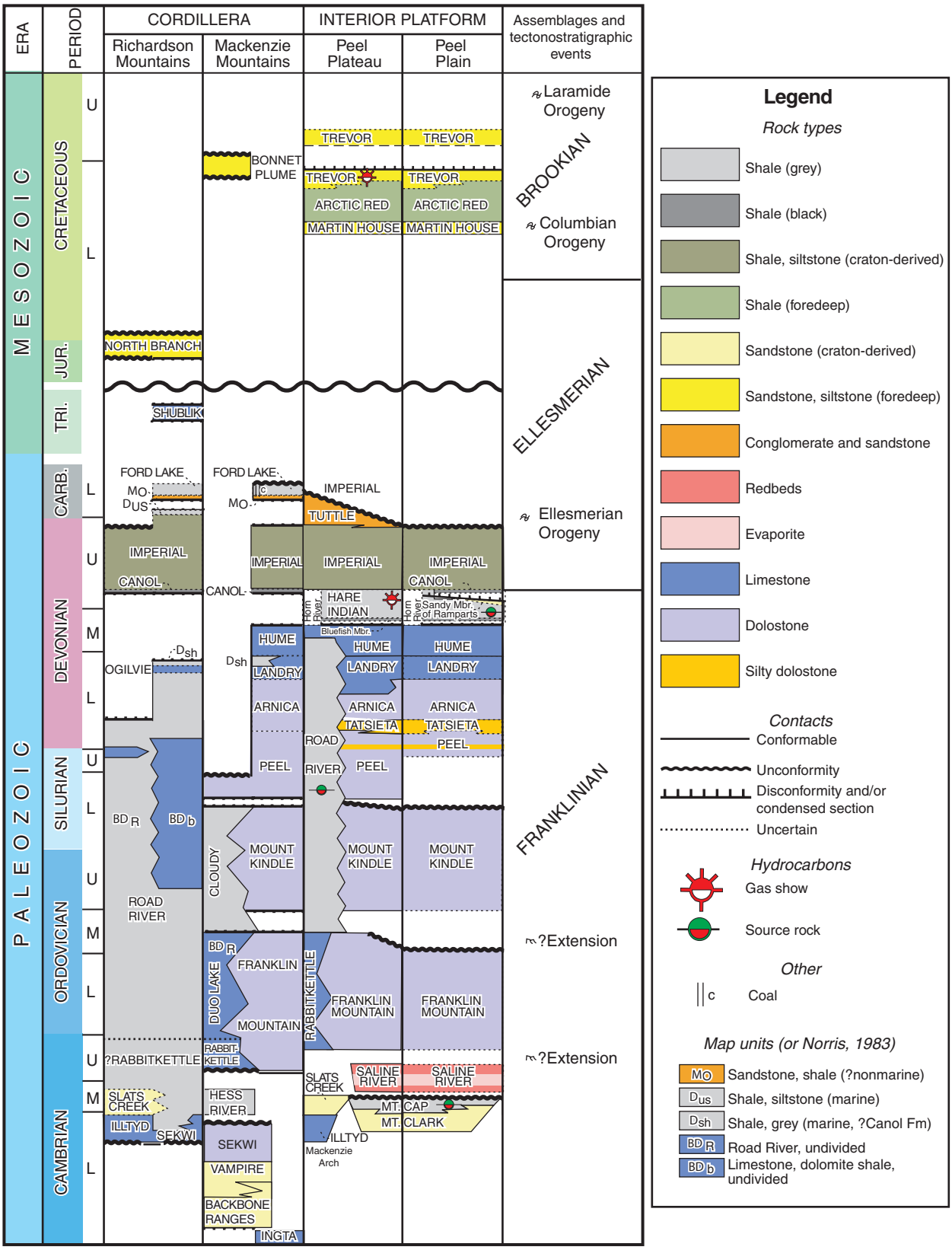

Figure 4. Preliminary Phanerozoic correlation chart for Peel region and proximal regions of the Cordillera and Interior Platform. The succession is divided into assemblages and key tectonostratigraphic events. Timescale *after* Okulitch (2004); stratigraphic data *after* Norris (1983, 1997) and Jones (2005). CARB. = Carboniferous, TRI. = Triassic, JUR. = Jurassic.

Cordillera (Cook and MacLean, 2004). Several phases of compression and extension throughout the Proterozoic influenced the complex development of Phanerozoic tectonic elements (Cook and MacLean, 2004; Thorkelson et al., 2005). Orange-weathering sandstone of the Katherine Group outcrops along the front of the Mackenzie Mountains, but was only observed underlying the Ronning Group at sections 2 and 4 (Table 1).

Cambrian to Middle Devonian

In general, Cambrian to Middle Devonian strata record sedimentation on the passive continental margin of ancestral North America (Fritz et al., 1992) and comprise the Franklinian Assemblage (Norris, 1996). In Peel region, Mackenzie Arch (Gabrielse, 1967; Gabrielse et al., 1973; Williams, 1987) separated Cambrian intracratonic depocentres of the Interior Platform from basinal settings to the west (Dixon and Stasiuk, 1998). Cambrian Mount Clark, Mount Cap, and Saline River formations have outcrop exposure just southeast of Peel region, whereas equivalent outboard facies outcrop south and westward (Fig. 4). Section 1 (Imperial Canyon) exposes Katherine Group (Fig. 5) to Imperial Formation from south to north along the river. Laudon (1950) measured 2519 m (8265 feet) of strata from the Cambrian to Cretaceous at this locality. Cambrian Mount Cap Formation is a pale-grey-, buff-, green-, red-, and black-weathering, mixed carbonate-siliciclastic unit of peritidal dolostone, sandstone, and black shale that includes potential source and reservoir rocks (Fig. 6). Mount Cap Formation is overlain abruptly by bright red-weathering, fine-grained sandstone, siltstone, and shale of Cambrian Saline River Formation (Fig. 7) which contains anhydrite and gypsum; this is a potential seal in the subsurface. Saline River Formation is overlain gradationally by grey- and buff-weathering, massive, shallow-water dolostone of ?Cambro-Ordovician Franklin Mountain Formation.

Across Peel region in the Cambrian to Middle Devonian, Mackenzie-Peel Shelf was a region of shallow-water deposition that passed westward and southwestward to basinal facies of the Road River Group within Richardson Trough and Selwyn Basin (Norris, 1985; Norford, 1996; Morrow, 1999). The carbonate platform succession of Peel region consists of the Ronning Group (Franklin Mountain and Mount Kindle formations), Delorme Group (Peel and Tatsieta formations), and Arnica, Landry, and Hume formations, which are overlain by the Horn River Group (Hare Indian, Ramparts, and Canol formations; Fig. 4). Franklin Mountain and Mount Kindle formations outcrop along the Mackenzie Mountains front (Fig. 8) and were examined and sampled for conodonts at sections 2, 3, and 4 (Table 1). The Franklin Mountain Formation contains up to four subunits (Norford and Macqueen, 1975) and is predominantly shallow-water dolostone with abundant oncolitic beds, and some limestone

Figure 5. Sandstone, dolostone, and shale of the Katherine Group, west side of Imperial Canyon, northern Mackenzie Mountains. Field of view is 50 m.

Figure 6. Stromatolitic dolostone masked by black shale of the Mount Cap Formation, Imperial Canyon (hammer head is 15 cm).

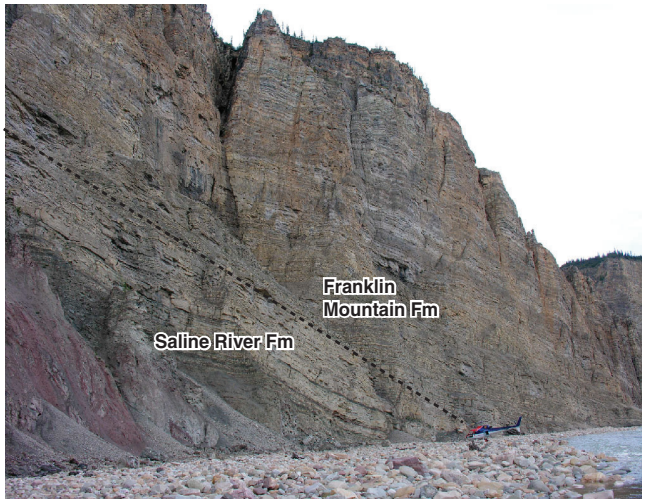

Figure 7. Red-weathering siltstone, shale, and sandstone of the Cambrian Saline River Formation overlain by dolostone of the ?Cambro-Ordovician Franklin Mountain Formation, west side of Imperial Canyon (helicopter for scale is 13 m).

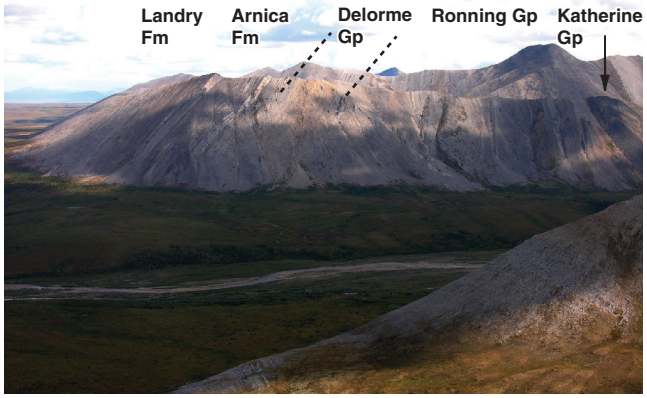

Figure 8. View east along Mackenzie Mountains Front showing Neoproterozoic to Devonian platform succession. Strata in foreground is 5 m thick.

beds to the west (Morrow, 1999). It is unconformably overlain by grey-weathering, fossiliferous Mount Kindle Formation, which contains vuggy porosity and is a potential reservoir rock. Silurian-?Devonian Delorme Group consists of orange-grey-weathering, silty dolostone and limestone of the Peel and Tatsieta formations (Fig. 4, 7), which are continuous along the Mackenzie Mountains front and thicken westward (Morrow, 1999).

The Road River Group (Rabbitkettle to Vittrekwa formations) represents basinal equivalents of ?Cambro-Ordovician Franklin Mountain Formation to Devonian platformal units (Fig. 4). Transitional and basinal Paleozoic strata occur at the Mackenzie-Peel Shelf to Selwyn Basin (Misty Creek embayment) transition south of the front of the Mackenzie Mountains (section 5, Fig. 3) and along the eastern flank of the Richardson Mountains (sections 6, 7, Fig. 3). Section 5 is a ridge section of carbonate debris flows, documented by Cecile (1982). Tetlit Creek (section 6, Fig. 9) is the type section of the Road River Formation (Jackson and Lenz, 1962), elevated to Road River Group by Fritz (1985), that contains distal turbidite sequences (siltstone and black shale), bedded chert, silty dolostone, and discontinuous beds of debris-flow breccia. Cecile et al. (1982) divided the Road River Group into three informal formations: Loucheux, Dempster, and Vittrekwa, present at Trail River (section 7, Fig. 3).

The Arnica-Landry-Hume formation succession occurs along the Mackenzie Mountains front (Fig. 8, Table 1). Platform carbonate of the overlying Bear Rock and Hume formations are the northernmost exposures at the front, whereas recessive Hare Indian, Canol, and Imperial formations have less relief and lie on the southern edge of Peel Plateau and Peel Plain. The Arnica Formation is dark- and light-grey-weathering, cyclical dolostone; the overlying Landry Formation is pale grey-weathering dolostone. The Hume Formation is predominantly fossiliferous limestone that is overlain by either black shale of the Canol Formation (Fig. 10) or black, silty limestone of the Hare Indian Formation (Fig. 11). Two additional carbonate units, Bear Rock Formation and Ramparts Formation (Fig. 11), observed at sections 9 and 10 occur in eastern Peel region and southeast of Peel region (Fig. 3, Table 1).

Upper Devonian to Carboniferous

Upper Devonian to Carboniferous strata include synorogenic siliciclastic rocks deposited in a foreland setting during the Ellesmerian Orogeny (Richards et al., 1996), when source lands were west and north of Peel region (Gordey et al., 1992). The Imperial Formation is extensive across Peel region and the Richardson and Mackenzie mountains. In western Peel

Figure 9. Type section of Road River Group, north side of Tetlit Creek, Richardson anticlinorium, containing black shale, siltstone, chert, silty dolostone, and debris-flow breccia (geologists for scale).

Figure 10. View west to fossiliferous limestone of the Hume Formation, overlain abruptly, but conformably by black shale of the Canol Formation, Flyaway Creek. Person in foreground for scale.

Plateau it is overlain by Tuttle Formation; in the Cordillera it is overlain by Tuttle and Ford Lake formations ((Richards et al. (1996); Fig. 4). The Imperial Formation outcrops along the southern edge of Peel Plateau and in the northwest corner of Peel region. The type section of the Imperial Formation (section 14, Fig. 12) is located southeast of Peel region on Mackenzie Plain and contains cycles of siltstone and shale up to 600 m thick. At one roadside locality along the Dempster Highway, a conformable mass of solid bitumen occurs within organic-rich siltstone, mudstone, and shale of the Imperial Formation (Fig. 13).

Cretaceous

Cretaceous siliciclastic rocks of Peel region were deposited during phases of rifting and compression that formed Peel Trough (Yorath and Cook, 1981; Dixon, 1999), a foreland setting created during the Columbian and Laramide orogenies (Norris, 1996). The Martin House, Arctic Red, and Trevor formations occur across Peel region (Mountjoy and Chamney, 1969). The pre-Cretaceous unconformity is a prominent hiatus across Peel region (Fig. 4). Cretaceous rocks outcrop along rivers (Fig. 14, 15) and resistant sandstone units form low-lying hills of the Peel Plateau.

PRELIMINARY RESULTS

Collections from key sections included Paleozoic carbonate rock for conodont microfossil analysis and Paleozoic and Mesozoic black shale for organic geochemical analysis. These reconnaissance data provide a framework for further evaluation of prospective stratigraphic horizons (source and reservoir facies), biostratigraphic dating of formations, and assessing hydrocarbon potential.

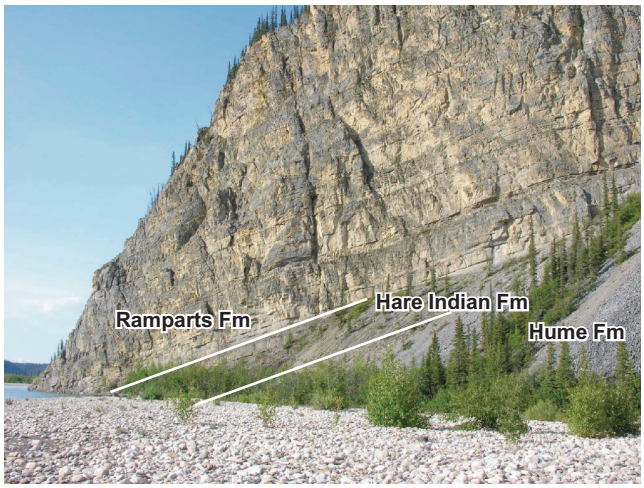

Figure 11. View north along Mountain River from Imperial anticline. Rubble of the Hume Formation in foreground overlain by recessive limestone and shale of the Hare Indian Formation and cliff-forming limestone of the Ramparts Formation. Field of view is about 50 m across.

Figure 12. View northeast to type section of the Imperial Formation, Imperial River, is a 600 m thick cyclic succession of grey, fine-grained, silty sandstone, and grey-black shale. Sheep (circled) shows scale.

Figure 13. View west to abandoned quarry near Rengleng River on the Dempster Highway exposes a black mass of bitumen, conformable with beds of brown and grey, organic-rich siltstone, mudstone, and shale of Imperial Formation (bitumen layer is about 1 m thick).

Figure 14. Type section of the Cretaceous Martin House and Arctic Red formations, east side of Peel River, Peel Plateau (geologist for scale at contact).

Figure 15. View north to exposure of Arctic Red Formation, Snake River, Peel Plateau. Exposed bank is about 30 m high.

Preliminary conodont ages and colour alteration index

A total of 31 conodont samples were taken from Paleozoic strata. Four of ten samples from the Ronning Group (sections 1, 2, 3, and 4) yielded Middle Ordovician conodonts from the upper Franklin Mountain Formation and base of Mount Kindle Formation. Conodonts from these formations have colour alteration indices (CAI) values of 4 and 5 (190ºC to 400ºC). Four of eight samples in the Delorme Group (sections 2, 3, and 8) yielded Late Ordovician to Silurian faunas with CAI values of 4 (190ºC to 300ºC). Silty and dolomitic samples from the Ordovician-Silurian Ronning and Delorme groups had poorer yields overall compared to Devonian limestone. Two samples of limestone from the Road River Group (section 6) yielded Silurian faunas of Ludlovian and Wenlockian age, with CAI 4.

Limestone samples from Devonian units all yielded conodonts with the exception of one dolomitic sample from the Arnica Formation (section 3) and one sample of Bear Rock Formation (section 9). Faunas span several conodont zones in the Emsian to Eifelian interval and can be correlated with the existing zonation for the Devonian of North America. Conodonts from this interval were recovered from the middle of the Landry Formation (section 8), top of Hume Formation (section 13), and base of the Hare Indian Formation (section 11). Only simple cones with CAI value of 2 (60ºC to 140ºC) were recovered from the Arnica Formation (section 8). The youngest conodonts from the Ramparts Formation are Givetian. Elements from the Landry, Hume, Hare Indian, and Ramparts formation samples also had CAI values of 2, although one Hume Formation sample (section 13) had a CAI value of 5. Specimens from the ? Hare Indian–Canol formation (section 12) had CAI values of 4, whereas those from the top of Hare Indian (section 10) had a CAI range of 2 to 4. The liquid window for oil generation (60ºC–120ºC) corresponds to CAI values of 1.5 to 2; the gas window (50ºC–300ºC) corresponds within CAI range of 1.0 to 4.5 in which dry gas and eventually barren strata occur in higher temperature ranges (110ºC– 300ºC) that correspond to CAI values of 3 to 4. The thermal limit for hydrocarbon production corresponds to CAI 4.5 (Harris et al., 1980).

Reconnaissance TOC values

Hydrocarbon potential and an indication of maturation for 14 outcrop samples collected as potential source rocks were obtained by Rock-Eval pyrolysis for TOC (Table 2). The Mount Cap, Saline River, Imperial, and ? Mount Goodenough formation samples have low TOC contents and are overmature with respect to hydrocarbon generation. Within this sample set, the highest TOC contents were recorded for the Devonian Canol and Hare Indian formation samples. The Hare Indian Formation sample, which has a very high TOC content (11.9%), is the least mature of the sample set with a T_{max} value (446°C) and HI value (248), suggesting it is in the later stages of the oil window with some remaining potential (but with a significant portion already realized). Road River Formation samples also have high TOC contents indicating original potential, but they are overmature. Cretaceous Arctic Red Formation samples are more difficult to assess, but could likely be minor source rocks for gas.

ONGOING THEMATIC STUDIES

The 'Peel Petroleum Project' addresses a number of knowledge gaps where new information is needed for a comprehensive basin analysis and resource assessment (Pyle et al., 2006). Fieldwork is planned for 2006 with a revisionary field season in 2007 to address a number of research questions.

Petroleum potential

For all parts of the succession, petroleum play data (source-rock potential and maturation, nature of reservoir rocks, trap types) are needed to characterize petroleum systems. Osadetz et al. (2005) assessed eight plays in three assessment regions in Yukon Territory (Peel Plateau west of Trevor Fault, Peel Plateau, and Peel Plain) that include a 'Paleozoic Carbonate

Table 2. Total organic carbon (%TOC) and Rock-Eval pyrolysis for TOC data; PI = production index, HI = hydrogen index, OI = oxygen index, S1 = S1 peak, S2 = S2 peak, – = no data.

Section	Latitude, longitude	Formation	C-number	TOC (%)	S1	S2	PI	T_{max} (°C)	HI	OI	Maturity	Original source potential
Dempster Highway	67°23.474′, 134°51.841′	?Mt. Good-enough	C-455001	0.52	0.04	0.17	0.18	–	33	2	Overmature	Poor
7	66°42.465′, 135°47.275′	Road River	C-455002	2.49	0.00	0.00	–	–	0	7	Overmature	Good
6	66°24.810′, 135°30.243′	Road River	C-455003	1.58	0.01	0.00	–	–	0	3	Overmature	Fair
13	65°26.710′, 132°02.053′	Canol	C-455004	4.60	0.00	0.05	–	–	1	3	Overmature	Excellent
16	66°05.406′, 134°04.381′	Arctic Red	C-455005	1.25	0.04	1.25	0.03	439	100	18	Early-mid mature	Minor gas
12	65°21.257′, 130°45.522′	Hare Indian or Canol	C-455006	2.58	0.00	0.06	0.02	–	2	4	Overmature	Good
11	65°20.362′, 129°57.588′	Canol	C-455007	8.51	0.17	2.51	0.06	497	29	10	Overmature	Excellent
14	65°06.698′, 127°51.134′	Imperial	C-455008	0.84	0.06	0.54	0.10	440	64	25	Overmature	Poor
1	65°06.095′, 128°02.542′	Mount Cap	C-455009	0.03	0.00	0.00	–	–	–	–	Overmature	None
1	65°06.465′, 128°01.953′	Mount Cap	C-455010	0.39	0.00	0.04	–	–	10	18	Overmature	None
1	65°06.465′, 128°01.953′	Mount Cap	C-455011	0.10	0.00	0.00	–	–	–	–	Overmature	None
1	65°06.465′, 128°01.953′	Saline River	C-455012	0.22	0.00	0.03	–	–	14	45	Overmature	None
15	65°25.732′, 129°53.969′	Arctic Red	C-455013	1.23	0.00	0.41	–	444	33	2	Late oil window	Minor
10	65°26.113′, 129°07.730′	Hare Indian	C-455014	11.92	0.20	29.55	0.01	446	248	13	Mid-late oil window	Excellent

Platform Play' in Peel Plateau and Peel Plain, 'post-Hume Reef' in Peel Plain, 'Upper Paleozoic Clastics Play' in all three regions, and 'Mesozoic Clastics Play' in Peel Plateau and Peel Plain. L.P. Gal and J.M. Lariviere (work in progress, 2006) outlined seven established and conceptual plays ('Basal Cambrian clastics', 'Cambro-Ordovician platform', 'Upper Devonian clastics', 'Arnica/Landry platform', 'Kee Scarp', 'Tuttle Formation', and 'Cretaceous clastics') in the Ts'ude'hliline-Tuyetah (Ramparts River and Wetlands) candidate protected area that has some coverage in Peel region.

Stratigraphy and correlation

A geological framework exists for Peel region (Fig. 4) and lithostratigraphic nomenclature has been refined (Morrow, 1999) and applied to the subsurface (Janicki, 2005). Priorities include documenting new detail from several sections visited during reconnaissance (as well as other new sections) and applying sequence stratigraphic analysis and new biostratigraphic information to improve correlation. There are also too few sections measured with detailed descriptions of units to permit understanding of facies relationships across Peel region and the adjacent Cordillera.

Sedimentology and diagenesis

Details on sedimentology of all parts of the succession are needed, particularly facies distributions and spatial relationships, and evaluation of reservoir rocks (porosity and thicknesses).

Structural geology and tectonic history

Structural analyses will be complemented by geophysical interpretations of seismic lines across Peel region. More information is needed on potential Laramide structural traps associated with the fronts of the Richardson and Mackenzie mountains, the influence of Proterozoic structures on overlying strata, and on the reorientation of the thrust and fold belt at the junction of the two mountain belts.

Organic geochemistry

New data (Rock-Eval pyrolysis for TOC) are needed to supplement existing thermal maturity data (vitrinite reflectance and Rock-Eval pyrolysis for TOC, summarized in Pyle et al. (2006)) in order to place the timing of hydrocarbon generation within the tectonic evolution of the basin.

ACKNOWLEDGMENTS

The authors thank the Polar Continental Shelf Program for helicopter support and Canadian Helicopters for excellent service. Yvon Lemieux critically reviewed the manuscript.

REFERENCES

Aitken, J.D., Ayling, M.E., Balkwill, H.R., Cook, D.G., Mackenzie, W.S., and Yorath, C.J.
1969: Fort Good Hope, District of Mackenzie; Geological Survey of Canada, Preliminary Map 4-1969, scale 1:250 000.

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

Bostock, H.S.
1970: Physiographic regions of Canada; Geological Survey of Canada, Map 1254A, scale 1:5 000 000.

Cecile, M.P.
1982: The Lower Paleozoic Misty Creek Embayment, Selwyn Basin, Yukon and Northwest Territories; Geological Survey of Canada, Bulletin 335, 78 p.

Cecile, M.P., Hutcheon, I.E., and Gardiner, D.
1982: Geology of the Northern Richardson Anticlinorium; Geological Survey of Canada, Open File 875, scale 1:125 000.

Cook, D.G. and Aitken, J.D.
1975: Ontaratue River (106 J), Travaillant Lake (106-O), and Canot Lake (106 P) map-areas, District of Mackenzie, Northwest Territories; Geological Survey of Canada, Paper 74-14, 44 p.

Cook, D.G. and MacLean, B.C.
2004: Subsurface Proterozoic stratigraphy and tectonics of the western plains of the Northwest Territories; Geological Survey of Canada, Bulletin 575, p. 1–92.

Dixon, J.
1999: Mesozoic-Cenzoic stratigraphy of the northern Interior Plains and plateaux, Northwest Territories; Geological Survey of Canada, Bulletin 536, 56 p.

Dixon, J. and Stasiuk, L.D.
1998: Stratigraphy and hydrocarbon potential of Cambrian strata, northern Interior Plains, Northwest Territories; Bulletin of Canadian Petroleum Geology, v. 46, p. 445–470.

Fritz, W.H.
1985: The basal contact of the Road River Group – a proposal for its location in the type area and in other selected areas in the Northern Canadian Cordillera; *in* Current Research, Part B; Geological Survey of Canada, p. 205–215.

Fritz, W.H., Cecile, M.P., Norford, B.S., Morrow, D., and Geldsetzer, H.H.J.
1992: Cambrian to Middle Devonian assemblages; *in* Geology of the Cordilleran Orogen in Canada, (ed.) H. Gabrielse and C. J. Yorath; Geological Survey of Canada, Geology of Canada, no. 4, p. 151–218 (*also* Geological Society of America, Geology of North America, v. G-2).

Gabrielse, H.
1967: Tectonic evolution of the northern Canadian Cordillera; Canadian Journal of Earth Science, v. 4, p. 271–298.

Gabrielse, H., Blusson, S.L., and Roddick, J.A.
1973: Geology of Flat River, Glacier Lake, and Wrigley Lake map-areas, District of Mackenzie and Yukon Territory; Geological Survey of Canada, Memoir 366, 153 p.

Gordey, S.P., Geldsetzer, H.H.J., Morrow, D.W., Bamber, E.W., Henderson, C.M., Richards, B.C., McGugan, A., Gibson, D.W., and Poulton, T.P.
1992: Part A. Ancestral North America; *in* Upper Devonian to Middle Jurassic assemblages, Chapter 8 of Geology of the Cordilleran Orogen in Canada, (ed.) H. Gabrielse and C. J. Yorath; Geological Survey of Canada, Geology of Canada, no. 4, p. 219–327 (*also* Geological Society of America, Geology of North America, v. G-2).

Harris, A.G., Wardlay, B.R., Rust, C.R., and Merrill, G.K.
1980: Maps for assessing thermal maturity (conodont colour alteration index maps) in Ordovician through Triassic rocks in Nevada and Utah and adjacent parts of Idaho and California; United States Geological Survey, Miscellaneous Investigations Series, Map I-1249, scale 1:250 000.

Jackson, D.E. and Lenz, A.
1962: Zonation of Ordovician and Silurian graptolites of northern Yukon, Canada; Bulletin of American Association of Petroleum Geologists, v. 46, p. 30–45.

Janicki, E.P.
2005: Northwest Territories Formation Tops, 60° to 68° North; Northwest Territories Geoscience Office, NWT Open Report 2005-006, 10 p.

Jones, A.L.
2005: Northwest Territories Oil and Gas Poster Series: Petroleum Resources, Table of Formations, Schematic Cross Sections; Northwest Territories Geoscience Office, NWT Open File 2005-06, 3 posters.

Laudon, L.R.
1950: Imperial River section, Mackenzie Mountains, Northwest Territories, Canada; Bulletin of the American Association of Petroleum Geologists, v. 34, p. 1565–1577.

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. and Geldsetzer, H.J.
1988: Devonian of the eastern Canadian Cordillera; *in* Devonian of the World, Proceedings of the Second International Symposium on the Devonian System; Volume I, Regional Syntheses, (ed.) N.J. McMillian, A.F. Embry, and D.J. Glass; Canadian Society of Petroleum Geologists, Memoir 14, p. 85–121.

Mossop, G.D., Wallace-Dudley, K.E., Smith, G.G., and Harrison, J.C.
2004: Sedimentary basins of Canada; Geological Survey of Canada, Open File 4673, 1 sheet.

Mountjoy, E.W. and Chamney, T.P.
1969: Lower Cretaceous (Albian) of the Yukon: stratigraphy and foraminiferal subdivisions, Snake and Peel rivers; Geological Survey of Canada, Paper 68-26, 71 p.

Norford, B.S.
1996: Ordovician and Silurian; *in* Geology and Mineral and Hydrocarbon Potential of Northern Yukon Territory and Northwestern District of Mackenzie, (ed.) D.K. Norris; Geological Survey of Canada, Bulletin 422, p. 119–162.

Norford, B.S. and Macqueen, R.W.
1975: Lower Paleozoic Franklin Mountain and Mount Kindle Formations, District of Mackenzie: their type sections and regional development; Geological Survey of Canada, Paper 74-34, 35 p.

Norris, A.W.
1968: Reconnaissance Devonian stratigraphy of northern Yukon Territory and northwestern District of Mackenzie; Geological Survey of Canada, Paper 67-53, 287 p.

Norris, D.K.
1981a: Geology, Arctic Red River, District of Mackenzie; Geological Survey of Canada, Map 1521A, scale 1:250 000.
1981b: Geology, Fort McPherson, District of Mackenzie; Geological Survey of Canada, Map 1520A, scale 1:250 000.
1981c: Geology, Martin House, Yukon-Northwest Territories; Geological Survey of Canada, Map 1525A, scale 1:250 000.
1981d: Geology, Trail River, Yukon-Northwest Territories; Geological Survey of Canada, Map 1524A, scale 1:250 000.
1982a: Geology, Snake River, Yukon-Northwest Territories; Geological Survey of Canada, Map 1529A, scale 1:250 000.
1982b: Geology, Wind River, Yukon Territory; Geological Survey of Canada, Map 1528A, scale 1:250 000.
1983: Geotectonic correlation chart - Operation Porcupine Project area; Geological Survey of Canada, Chart 1532A, 1 sheet.
1985: Geology of the northern Yukon and northwestern District of Mackenzie; Geological Survey of Canada, Map 1581A, scale 1:500 000.
1996: Geological setting; *in* Geology and Mineral and Hydrocarbon Potential of Northern Yukon Territory and Northwestern District of Mackenzie, (ed.) D.K. Norris; Geological Survey of Canada, Bulletin 422, p. 21–64.
1997: Geology and mineral and hydrocarbon potential of northern Yukon Territory and northwestern District of Mackenzie; Geological Survey of Canada, Bulletin 422, 397 p.

Norris, D.K., Hughes, O.L., and Thompson, R.I.
1992: G-19: A Geological Guide for the Dempster Highway, NWT and YT; Canadian Society of Petroleum Geologists, 58 p.

Okulitch, A.V.
2004: Geologic time chart, 2004; Geological Survey of Canada, Open File 3040, 1 sheet.

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

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/Northwest Territories Geoscience Office, Open Report 2006-01 (CD-ROM).

Richards, B.C., Bamber, E.W., and Utting, J.
1996: Upper Devonian to Permian; *in* Geology and Mineral and Hydrocarbon Potential of Northern Yukon Territory and Northwestern District of Mackenzie, (ed.) D.K. Norris; Geological Survey of Canada, Bulletin 422, p. 201–251.

Stott, D.F. and Klassen, R.W.
1993: Geomorphic divisions; Subchapter 2C *in* Sedimentary Cover of the Craton in Canada, (ed.) D.F. Stott and J.D. Aitken; Geological Survey of Canada, Geology of Canada, no. 5, p. 31–44 (*also* Geological Society of America, The Geology of North America, v. D-1).

Thorkelson, D.J., Abbott, J.G., Mortensen, J.K., Creaser, R.A., Villeneuve, M.E., McNicoll, V.J., and Layer, P.W.
2005: Early and Middle Proterozoic evolution of Yukon, Canada; Canadian Journal of Earth Sciences, v. 42, p. 1045–1071.

Williams, G.K.
1987: Cambrian geology of the Mackenzie Corridor; Geological Survey of Canada, Open File 1429, 58 p.

Yorath, C.J. and Cook, D.G.
1981: Cretaceous and Tertiary stratigraphy and paleogeography, northern Interior Plains, District of Mackenzie; Geological Survey of Canada, Memoir 398, 76 p.

Geological Survey of Canada Project MV5001