ERCB/AGS Open File Report 2009-19

Overview of Uranium Exploration Work Along the Northern Rim of the Athabasca Basin, Northeastern Alberta

Energy Resources Conservation Board

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Abstract

In Alberta, the northern rim of the Athabasca Basin and the regolith underlying the Athabasca unconformity are locally exposed along the northern shore of Lake Athabasca. Extensive uranium exploration work in the 1970s, including scintillometer prospecting traverses, geological mapping, airborne and ground geophysics, and drilling, have documented several uraniferous outcrops with scintillometer readings of up to 10 000 counts per second, and uraniferous boulders and boulder trains with radioactivity up to two orders of magnitude higher than the background. Near the Alberta-Saskatchewan border, uraniferous boulders show geochemical characteristics consistent with a Saskatchewan source, whereas to the west boulders have a distinct geochemical signal suggesting a local source in Alberta.

Six days of float plane-supported fieldwork by the authors in August 2004 confirmed the location of the Athabasca unconformity along the northern shore of Lake Athabasca and enabled examination of outcrops on both sides of the unconformity. Scintillometer traverses over previously defined radioactive boulder fields, and examination of the locations where individual radioactive boulders were reported, could not confirm the positive metallogenic indicators reported during the intense exploration in the 1970s. Uranium metallogenetic indicators extracted from industry assessment reports (location of boulder fields and individual boulders, drillhole locations), as well as mineral occurrences (including many uraniferous sites) identified north of Lake Athabasca by the provincial and federal geological surveys, have been compiled in GIS format.

1 Introduction

The Athabasca Basin, which straddles the Alberta-Saskatchewan border, contains some of the greatest uranium resources in the world, with deposits one or two orders of magnitude larger than most other deposits elsewhere. The great majority of mines and prospects in Saskatchewan are located where the Athabasca Group unconformably overlies the western Wollaston and Wollaston-Mudjatik transition basement domains. However, significant mined deposits and prospects also exist near Cluff Lake in the Carswell Structure, and new prospects have been intersected by drilling at Shea Creek (Rippert et al., 2000) and Dragon Lake along the Maybelle River shear zone (Wheatley in Pană et al., 2007). These discoveries demonstrate the potential for similar unconformity-associated uranium deposits in the western part of the Athabasca Basin.

The Alberta portion of the basin was intensely explored in the 1970s and early 1980s, and uranium occurrences have been documented in drillcore along the Maybelle structural trend south of Lake Athabasca and in a few outcrops north of the lake. However, low prices of uranium in the 1980s and 1990s led to a loss of interest in the uranium potential of the area. Increases in the uranium price, from ~$10 US/lb U_3O_8 in September 2003 to ~$37 US/lb U_3O_8 in January 2006 (and $91 US/lb U_3O_8 in May of 2007) prompted the almost complete re-staking of the Alberta portion of the Athabasca Basin, and locally, of the adjacent basement (Figure 1). Favourable premises for uranium exploration in Alberta include

1) the extension into Alberta of the main stratigraphic units of the Athabasca Group associated with uranium deposits in Saskatchewan;

2) lithological and geochemical similarities of basement units underlying the Athabasca Group in Alberta to Saskatchewan's highly prospective Wollaston Fold Belt; and

3) the presence of ancient shear zones locally overprinted by faults. Consequently, the Alberta Geological Survey (AGS) has embarked on a systematic re-evaluation of the uranium potential of the area.

Between August 10 and August 16, 2004, reconnaissance work by AGS was conducted along the northern shore of Lake Athabasca and a few kilometres inland around Greywillow Point, Cypress Point, Fallingsand Point, Fidler Point and Sand Point (Figure 1). This area has been extensively 'staked' as mineral permits during the last half of 2004 and the first half of 2005. This report includes a preliminary assessment of the uranium metallogenic indicators along the northern rim of the Athabasca Basin in Alberta, based on our field work and a review of previous industry work, as reported in assessment reports submitted to the Alberta government and an overview of selected articles on the Athabasca unconformity–associated uranium deposits. The base map shown in Figure 1 is a composite image (geotiff) produced by fusing Indian Remote Sensing (IRS) imagery with the geological map of the Alberta sheild at a scale of 1:250 000 compiled by Godfrey (1986a). The IRS imagery offers the best horizontal accuracy (30 m with a 90% level of confidence) and is currently used by the Department of Sustainable Resource Development (SRD) to update the Alberta base map features (with horizontal accuracies of 125 m for 1:250 000 maps and of 50 m for 1:50 000 maps). For more information on the accuracy of base maps in any particular area of interest, visit the Geological Survey of Canada web page http://maps.nrcan.gc.ca/search/ntsquery.html

Assessment reports considered in this overview are listed in Table 1. Summaries of work performed, main results and recommendations of original authors for further work are included in Appendix 1 accompanying this report. Valuable exploration information extracted from existing exploration industry and government geological reports are provided as digital files (shapefiles):

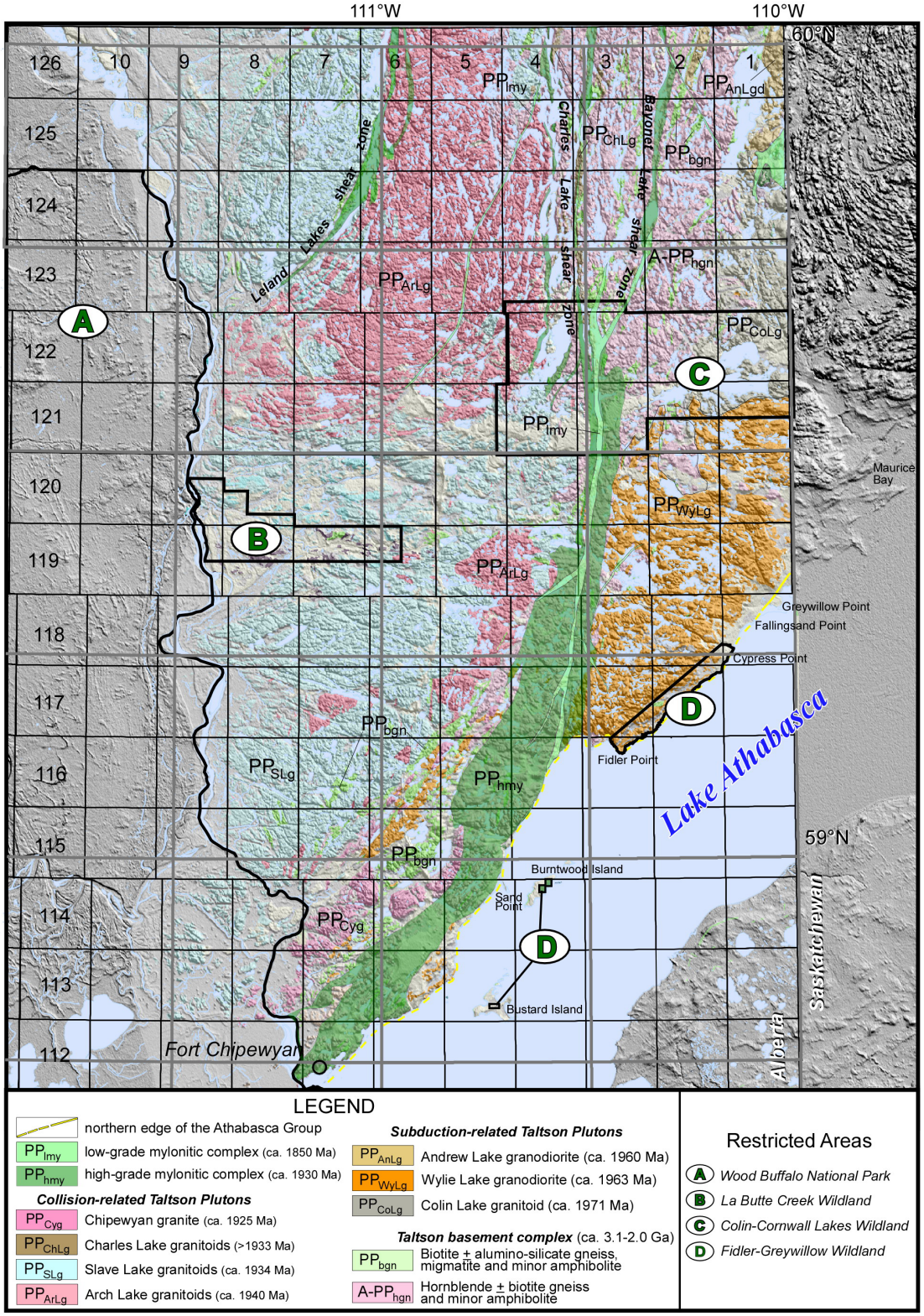


Figure 1. Simplified geological map of the Alberta sheild, modified after Godfrey (1986a) and McDonough et al. (2000a); U-Pb geochronology after McDonough et al. (2000a) and McNicoll et al. (2000). For current land disposition in the region see "Interactive Metallic and Industrial Minerals Map" at http://www.energy.gov.ab.ca/2741.asp.

Table 1. Existing assessment reports on uranium exploration north of Lake Athabasca, Alberta.

AGS ID Number	Report Title	Report Year	Author	Company	Reported Work Period	Permit	Area* (acres)	Location**	
19700011	Reconnaissance Property Examination of mineral permits nos. 125, 126 & 137, Northeastern Alberta	1970	Netolitzky, R.K.	Unity Resources Ltd.	04/08/1970 to 25/08/1970	125 126 137	40,000 30,000 10,000	Fidler Point, Belinda Lake, Florence Lake, Block Lake	Lat. 59°2'17" to 59°12'45"; Long. 110°20'46" to 110°51'30" Lat. 59°7'31" to 59°17'59"; Long. 110°20'46" to 110°41'16" Lat. 59°12'45" to 59°23'13" Long. 110°20'46" to 110°41'46"
19750007	Uranerz Exploration and Mining Ltd.'s final report 1975, Project 71-41, northwest Athabasca	1975	Lehnert-Thiel, K.	Uranerz	late 1974 and 19/08/1975 to 30/08/1975	189, 190	512,000	Ab/Sk border; Greywillow, Belinda Lake, Cypress Point	Lat. 58°45' to 59°45'; Long. 108°15' to 111°00'
19760006	Uranerz Exploration and Mining Ltd. yearly report 1976, northwest Athabasca, Project 71-41	1976	Lehnert-Thiel, K. and Kretschmar, W.	Uranerz	03/1976 to 12/1976	5 claims SK 5 permits AB	42,751 (SK) 49,600 (AB)	AB/Sask border; Sand Point, Fallingsand Point and Maurice Bay	Lat. 58°45' to 59°45'; Long. 108°15' to 111°00'
19770006	Geological report on permits 193 and 194, Project 71-41 and 7-60, Sand Point Area, Alberta	1977	MacMahon, M.	Uranerz	16/08/1977 to 01/09/1977	193, 194	39,680	30 km NE of Ft. Chipewyan	Lat. 59°00'; Long. 110°45'
19780001	Uranerz Exploration and Mining Ltd., yearly report, quartz mineral exploration permits no. 189 and 190, Alberta	1978	Lehnert-Thiel, K., Rich, J. and Harmeson, B.	Uranerz	08/1974 to 03/1978	193, 194	39,680	Sand Point, Shelter Point	Lat. 58°49' to 59°05'; Long. 110°48' to 110°52'
19780003	Uranerz Exploration and Mining Ltd. summary of exploration program - Alberta, quartz mineral exploration permits #189, 190, 193 and 194	1978	Lehnert-Thiel, K., Rich, J. and Harmeson, B.	Uranerz	01/04/1977 and 05/08/1977	189, 190, 193, 194	19,840	Greywillow, Point, Fallingsand Point, Sand Point, Shelter Point	Lat. 59°18'; Long. 110°05' ; Lat. 59°14'; Long. 110°10'
19780004	Uranerz Exploration and Mining Ltd. Yearly Report, quartz mineral exploration permits no. 193 and 194, Alberta	1978	Lehnert-Thiel, K., Rich, J. and Harmeson, B.	Uranerz	22/08/1977 to 01/09/1977 16/08/1977 to 01/09/1977	193, 194	19,840	Shelter Point and Sand Point	Lat. 58°55'; Long. 110°45'
19790009	Geological and geophysical report on permit 244, NE Alberta	1979	Kilby, D.B. and Walker, G.I.	C.&E. Explorations Ltd.	07/05/1979 to 31/05/1979	244	11,510	AB/Sask border; 98 km NE of Ft. Chipewyan	Lat. 110°3'49" to 110°5'33"; Long. 59°20'36" to 59°22'21" Lat. 110°5'33" to 110°0'23"; Long. 59°23'13" to 59°22'21" Lat. 110°0'23" to 110°5'33"; Long. 59°23'13" to 59°24'5" Lat. 110°3'49" to 110°5'33"; Long. 59°24'5" to 59°25'5"
19800006	Report on field examination of the quartz mineral permits, Northeastern Alberta	1980	Ward, R.	Farmers Chemical Ltd.	08/1980	unspecified	218,240	Tulip Lake, N of Ft. Chipewyan, S Colin Lake	Several poorly defined areas spread across the Alberta sheild.
19990015	Geological study of the Fidler Point property in NE Alberta	1999	Dick, D. L.	Mine-Geo Research Inc.	09/1998 to 10/1998	9397020001	19,791	Fidler Point	Lat. 110°30'35" to 110°20'46"; Long. 59°12'32" to 59°7'31"

Table 1. Assessment reports on uranium exploration north of Lake Athabasca, Alberta, discussed in the present overview.

Note:

* Explored areas in the table are converted to acres from various measurement units used in assessment reports (1 kilometre^2 = 247.1 acre; 1 mile^2 = 640 acre; hectare = 2.47 acre)

** Locations reported by original authors in township-range or decimal latitude-longitude systems have been converted for consistency.

- locations of diamond drillholes near Fallingsand Point (DIG 2005-0015);
- locations of uranium boulders (DIG 2009-0018) and uranium boulder trains (DIG 2009-0019) along the northern shore of Lake Athabasca in Alberta;
- 'uranium sites' (i.e., sites of uranium mineral stains and/or radioactivity) discovered during the 1957 to 1975 mapping of the Alberta sheild carried out by the Alberta Research Council and summarized in Godfrey (1986b) (DIG 2009-0020); and
- metallic mineral showings re-examined and new sites identified by AGS (Langenberg and Eccles, 1996) during the Canada-Alberta Mineral Development Agreement in the early 1990s (DIG 2009-0021).

2 Physiography and Access

The area under investigation is located on the northern shore of Lake Athabasca and encompasses crystalline rocks of the Canadian Shield and clastic strata of the Athabasca Group. Lake Athabasca is relatively shallow in Alberta, being less than 5 m deep west of Burntwood Island, reaches a depth of 16 m along its axis to the northeast and deepens into Saskatchewan to over 120 m in Black Bay, west of the Crackingstone Peninsula. Along its northern shore in Alberta, Lake Athabasca is less than 5 m deep between Fort Chipewyan and Fidler Point, and between 8 m and 11 m between Fidler Point and the Alberta-Saskatchewan border. Seasonal water level elevation variations range from approximately 209 to 212 m above sea level (Canadian Hydrographic Services, 1978) The topography of the Shield north of the lake consists primarily of monotonous, low rounded ridges whose maximum relief seldom exceeds 70 metres, interspersed by numerous lakes, small areas of muskeg and some broad sand plains. The entire area has been glaciated, with the ice advance direction predominantly 265° (Bednarsky, 1999). Exposure is generally good, especially in areas underlain by massive granite or granite gneiss, whereas structural lineaments are emphasized by differential erosion and weathering and thus commonly form topographic lows. Outcrops of the Athabasca Group have been intensely, but more uniformly, eroded. The country is rugged except for the region along the shoreline, which is covered by sand plains, raised beaches and swamps. Sand and clay lake deposits occur in several low-lying areas. Some of the sand plains along Lake Athabasca are up to 3 kilometres wide and may be underlain by the Athabasca Group.

The climate is extreme continental with temperatures as low as -60°C in winter and up to +30°C in summer. In early May, temperatures are often below freezing and the ground is still snow covered, whereas toward the end of May temperatures are above freezing and most of the snow has melted. The vegetation consists mainly of jack pine and spruce.

Fort Chipewyan in Alberta and Uranium City in Saskatchewan are the only sizeable hamlets on the northern shore of Lake Athabasca. An Alberta Government Forestry cabin formerly existed two miles west of Fidler Point on the shore of Lake Athabasca (Netolitzky, 1970) and remnants of exploration camps and hunting cabins have been noticed west of Greywillow and Fidler promontories. The most convenient means of access to the area is by boat and float-equipped aircraft during the summer months and by ski-equipped aircraft and snowmobiles during the winter. Helicopters can also be used effectively in both summer and winter, and are available for casual charter in Fort McMurray. Heavy freight and supplies can be transported to the area via barge services, which connect Lake Athabasca to the railhead at Fort McMurray, Alberta. Lake Athabasca and numerous inland lakes are adequate for floatplane operations, and could supply water for diamond-drilling operations. Service from the air may not be possible in times of moderate to strong winds because of the potential for large and treacherous wave action on Lake Athabasca.

3 Previous Work

In the 1970s, significant uranium deposits were discovered along the crystalline basement/Athabasca Group unconformity (e.g., Rabbit Lake, Cluff Lake) and along the crystalline basement/Martin Formation unconformity (e.g., some of the Uranium City deposits). Along Lake Athabasca's shore, pitchblende had been reported east of the Alberta-Saskatchewan border. Uraniferous sandstone boulders and boulder trains have been reported on both sides of the border along the shore at abandoned beach levels located 10 to 17 metres above the current lake level and more rarely at the base of ridges. The origin of the uranium deposits was thought to be supergene, with minor mobilization and redeposition (e.g., Derry, 1970).

Assessment reports on file with the Alberta Geological Survey describe geological and geophysical exploration work relevant to uranium exploration in different parts of the Alberta sheild and can be found at www.ags.gov.ab.ca/publications. The scope of the present overview was limited to industry reports on uranium exploration work along the rim of the Athabasca Basin, roughly coincidental with the northern shore of Lake Athabasca. The common denominator of the reviewed reports is the identification of radioactive uranium boulders, which are often used as up-ice tracers to source a possible uranium resource. A list of these reports with authorship, respective permits and encompassing areas is in Table 1. Exploration activities, main exploration results and recommendations by the original workers for each property are summarized in Section 5. The location of the former mineral properties for which results have been compiled is shown in Figure 2. One of the listed assessment reports, Ward (1980), consists of less than two pages of text and a set of topographic maps with inferred U/Th anomalies within several permit areas (north of Fort Chipewyan, southeast of Fort Smith and south of Colin Lake) based on the Airborne Gamma-Ray Spectrometric Map scale 1:250 000 published by the Geological Survey of Canada in late 1970s. The work and results are insufficiently documented and will not be discussed here.

Regional geological information relevant to uranium exploration in northeastern Alberta has been published by both federal and provincial geological surveys. Thus, in the 1960s and early 1970s, regional geological maps for Alberta available for uranium exploration included a preliminary geological map by the GSC (Riley, 1960) and an aerial photographic interpretation of Precambrian structures north of Lake Athabasca (Godfrey, 1958). The area was covered by aeromagnetic maps (1:63 360) surveyed by Canadian Aero Service Ltd. in 1961 as part of the federal-provincial program for aeromagnetic coverage of the Precambrian Shield. The lines were flown at an altitude of 1000 feet at half-mile intervals (i.e., at about 305 m altitude and 800 m between lines).

Between 1957 and 1975, Godfrey of the Alberta Research Council carried out systematic geological mapping and sampling of the Alberta sheild, and between 1961 and 1984 he published 11 geological reports (see References), including 32 geological map sheets at 1:31 680 scale (available as PDFs at www.ags.gov.ab.ca/publications). Between Fort Chipewyan and the Alberta-Saskatchewan border, the northern shore of Lake Athabasca is covered by Godfrey's map sheets 13, 15, 16 (Godfrey, 1980a), 23 (Godfrey, 1984), 18 and 19 (Godfrey, 1980b; Figure 3). The mapping effort was supported by studies of igneous, metamorphic and fault rocks petrogenesis (e.g., Watanabe, 1965; Godfrey and Langenberg, 1978; Nielsen et al., 1981), structural studies (e.g., Godfrey, 1958; Langenberg, 1983) and geochronological studies (e.g., Baadsgaard and Godfrey, 1967, 1972; Kuo, 1972; Day, 1975). Based on his mapping and mineral exploration work, Godfrey published a geological compilation map (Godfrey, 1986a) and a map of mineral showings on the Alberta sheild (Godfrey, 1986b). His mineral showings map included uranium occurrences (defined by the author as "yellow stain and/or radioactivity") close to the northern shore of Lake Athabasca, mainly north of Fidler Point, a large number of uranium occurrences around and between Colin and Andrew lakes, and isolated occurrences along shear zones (Figure 4). A number of these occurrences that have been re-examined and other new occurrences identified by Langenberg and

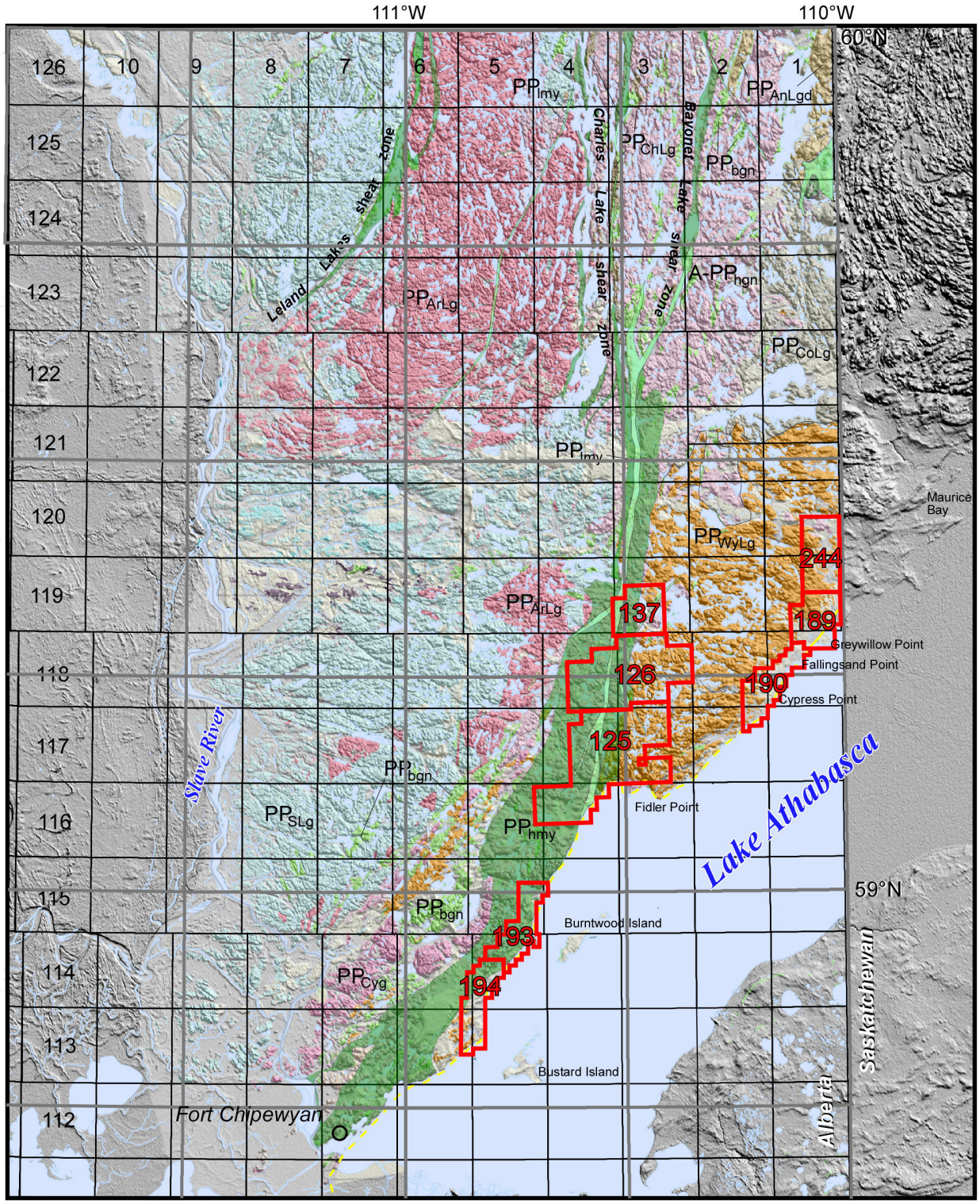


Figure 2. Mineral permits explored for uranium north of Lake Athabasca in the 1970s whose assessment reports are considered in the present overview. See Figure 1 for legend.

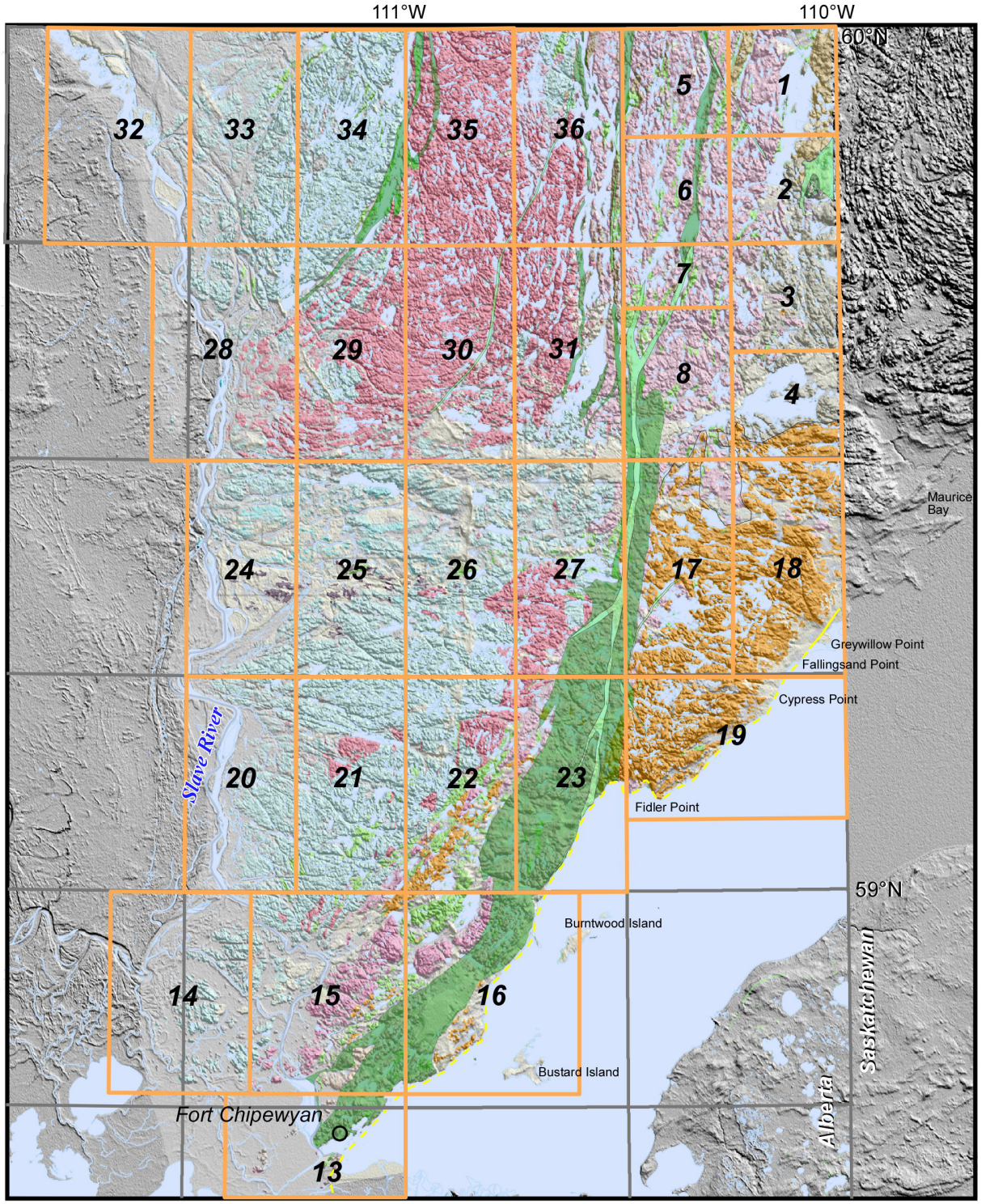
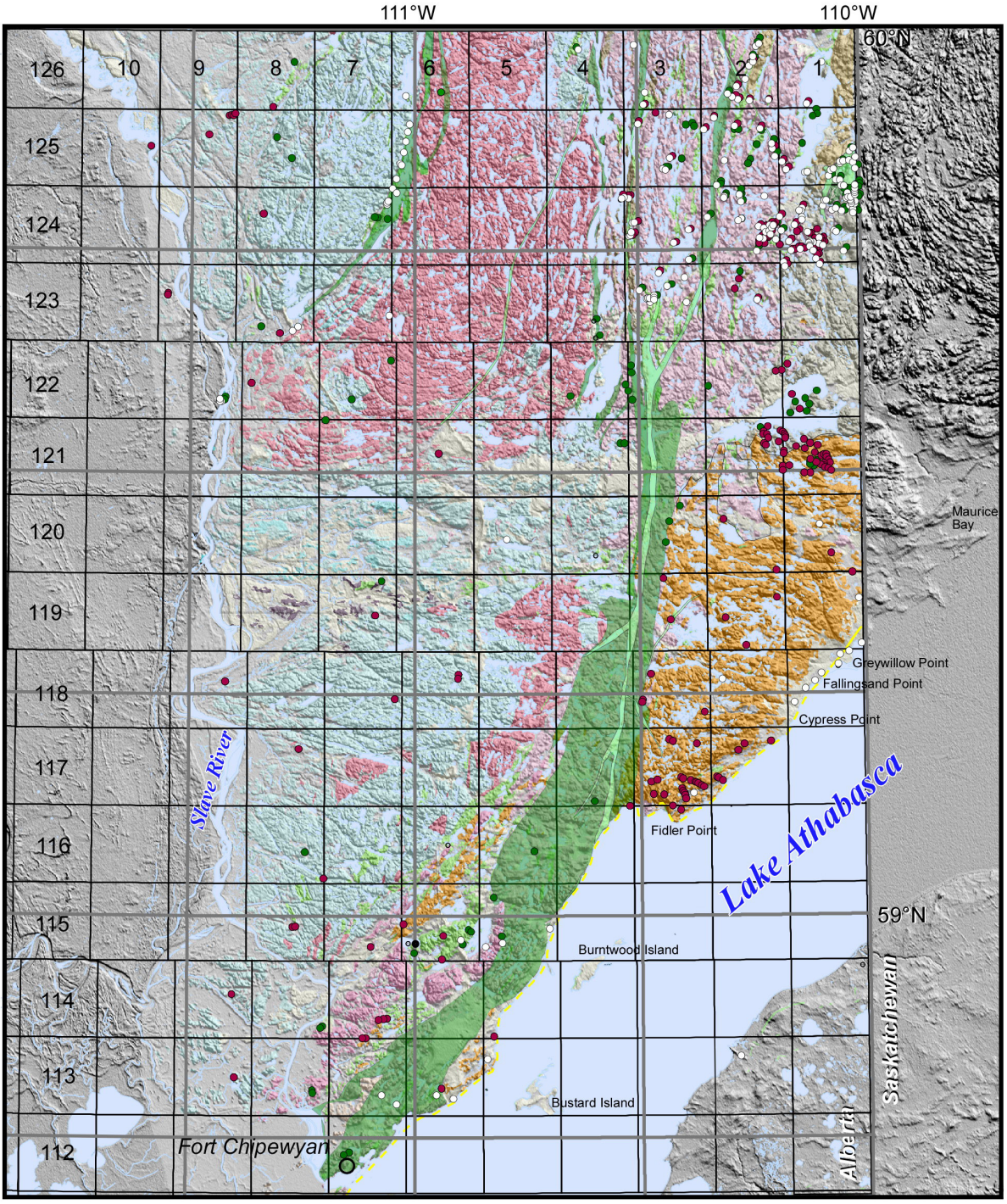


Figure 3. Geological map areas, scale 1:31 680 published by the Alberta Research Council/Alberta Geological Survey (Godfrey, 1961, 1963, 1966, 1980a, 1980b, 1984, 1987; Godfrey and Peikert, 1963, 1964; Godfrey and Langenberg, 1986, 1987). See Figure 1 for legend.



- Uranium showings (“yellow stain and/or radioactivity”)
- Various mineral showings including allanite, possible regolith, tourmaline, graphite, sulphide

Figure 4. Mineral showings identified during detailed geological mapping of the Alberta sheild by the Alberta Research Council/Alberta Geological Survey between 1957 and 1975 and compiled by Godfrey (1986b) shown as coloured dots. White dots are re-examined sites and newly identified sites by Langenberg and Eccles (1996). See Figure 1 for legend.

Eccles (1996) are represented in Figure 4. The geophysical expression of the Alberta sheild, including aeromagnetic and gravity maps, as well as a radiometric map with anomalously high values and a series of radiometric profiles, have been published by Sprenke et al. (1986). A summary of petrological and geochemical data for the Alberta sheild has been published by Goff et al. (1986). Regional GSC gravity and magnetic data of the eastern half of northern Alberta (north of 55° N), including the Alberta sheild, have been processed for fault identification and most relevant geophysical maps released as PDFs and geotiffs (Lyatsky and Pană, 2003).

Between 1992 and 1995, the Alberta sheild was remapped in part at a scale of 1:50 000 by the Geological Survey of Canada under the auspices of the Canada-Alberta agreement on mineral development (MDA) project. Six "A" series maps were released by the GSC in 2000 and five maps have been included in Open File reports (Figure 5), with much of the information compiled from existing Alberta Geological Survey maps of Godfrey and his coauthors. However, geochronology, geochemistry, petrology, isotopic and structural studies done by the GSC greatly improved the understanding of the geological evolution of the Alberta sheild (e.g., Thériault, 1992; Grover et al., 1997; Chacko et al., 2000; De et al., 2000; McDonough et al., 2000g; McNicoll et al., 2000; Schetselaar, 2000). GSC geochemical data from newly identified mineral showings (see Figure 6 for location) were included in McDonaugh et al. (1994a). Regional airborne geophysical maps (including gamma-ray spectrometry) that encompass the Alberta sheild were published by Charbonneau et al. (1994) and Carson et al. (2002).

4 Geological Setting

The area considered in this report is located along the northern erosional edge or unconformity between the crystalline basement and the Athabasca Group in northeastern Alberta (Figure 7). The Fair Point Formation, which is the oldest stratigraphic unit deposited in the ca. 1.7 to 1.5 Ga Athabasca Basin, is poorly exposed along the northern shore of Lake Athabasca. To the north, the Alberta sheild encompasses crystalline basement rocks of the Taltson magmatic zone (TMZ; e.g., McDonough et al., 2000g). Recent processing of regional geophysical data and enhancement of basement-sourced gravity and magnetic anomalies in areas covered by Proterozoic or Phanerozoic strata, corroborated with petrography and sensitive high-resolution ion microprobe (SHRIMP) zircon dating of granitoid rocks (Lyatsky and Pană, 2003; Stern et al., 2003), confirmed that the Taltson magmatic zone extends to the south under the western Athabasca Basin. Shield lithological units that have been mapped along the rim of the basin, including the Wylie Lake and Fishing Creek granitoids, are known to be associated with a uraniferous zone at Dragon Lake along the Maybelle River shear zone, Alberta (Pană et al., 2007).

The TMZ includes a plethora of ca. 1.99 to 1.92 Ga granitoid rocks that intruded and reworked Archean to Early Proterozoic crust at the northwestern margin of Rae terrane (e.g., Chacko et al., 2000; McDonough et al., 2000g; McNicoll et al., 2000). A simplified geological map of the Alberta sheild is included in Figure 7. Although the geological units of the TMZ have been mapped and dated in detail, its tectonic setting and evolution is still controversial with three competing tectonic models (Figure 8). Originally defined as a series of complex, northerly trending aeromagnetic anomalies that encompass most of northern Alberta (Hoffman, 1988), the TMZ was subdivided based on isotope dating of basement drill core into distinct domains accreted to Laurentia (e.g., Ross et al., 1991; Ross, 2002). The main phases of the accretion scenario are represented in Figure 8a. A ca. 2.13 to 2.09 Ga basin, called Rutledge River Basin, was postulated between the Archean Rae terrane to the east and the Early Proterozoic Buffalo Head terrane to the west (Bostock and van Breemen, 1994; Ross, 2002). The TMZ was thus redefined as a narrower belt in northeastern Alberta that would represent a cryptic suture zone between the Buffalo Head island arc to the west and the Rae continent to the east. Petrographical, geochemical and isotope data were interpreted to indicate that the TMZ evolved from a continental magmatic arc to the core of a collisional orogen (e.g., Ross et al., 1991; McDonough et al., 2000g; Ross, 2002). However, recent geochemical and

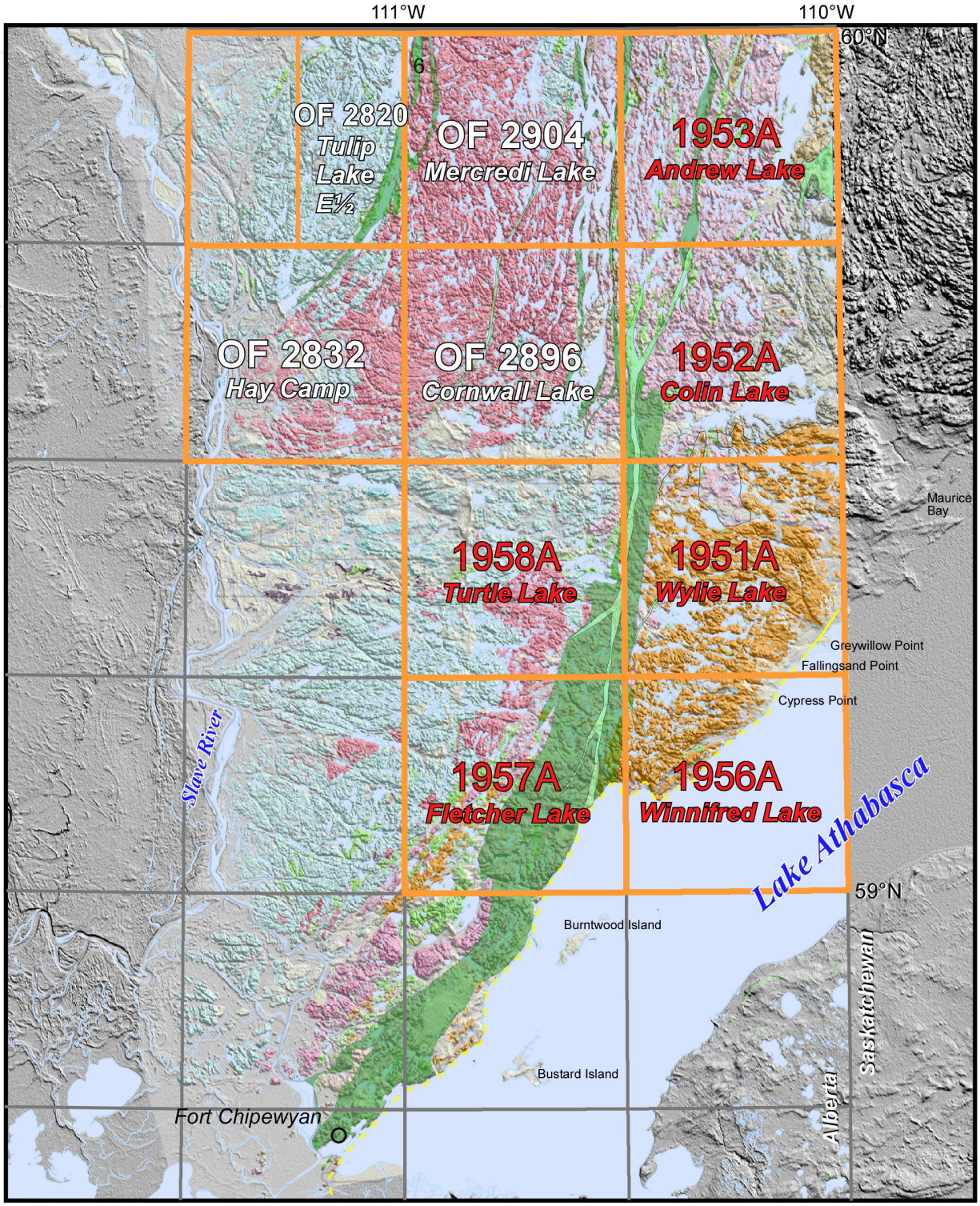


Figure 5. Geological maps of the Alberta sheild scale 1: 50 000 published by the Geological Survey of Canada. In white - GSC Open File Reports (McDonough et al., 1994b, c, d, e); in red - GSC 'A Series' Maps (McDonough et al., 2000a, b, c, d, e, f). See Figure 1 for legend.

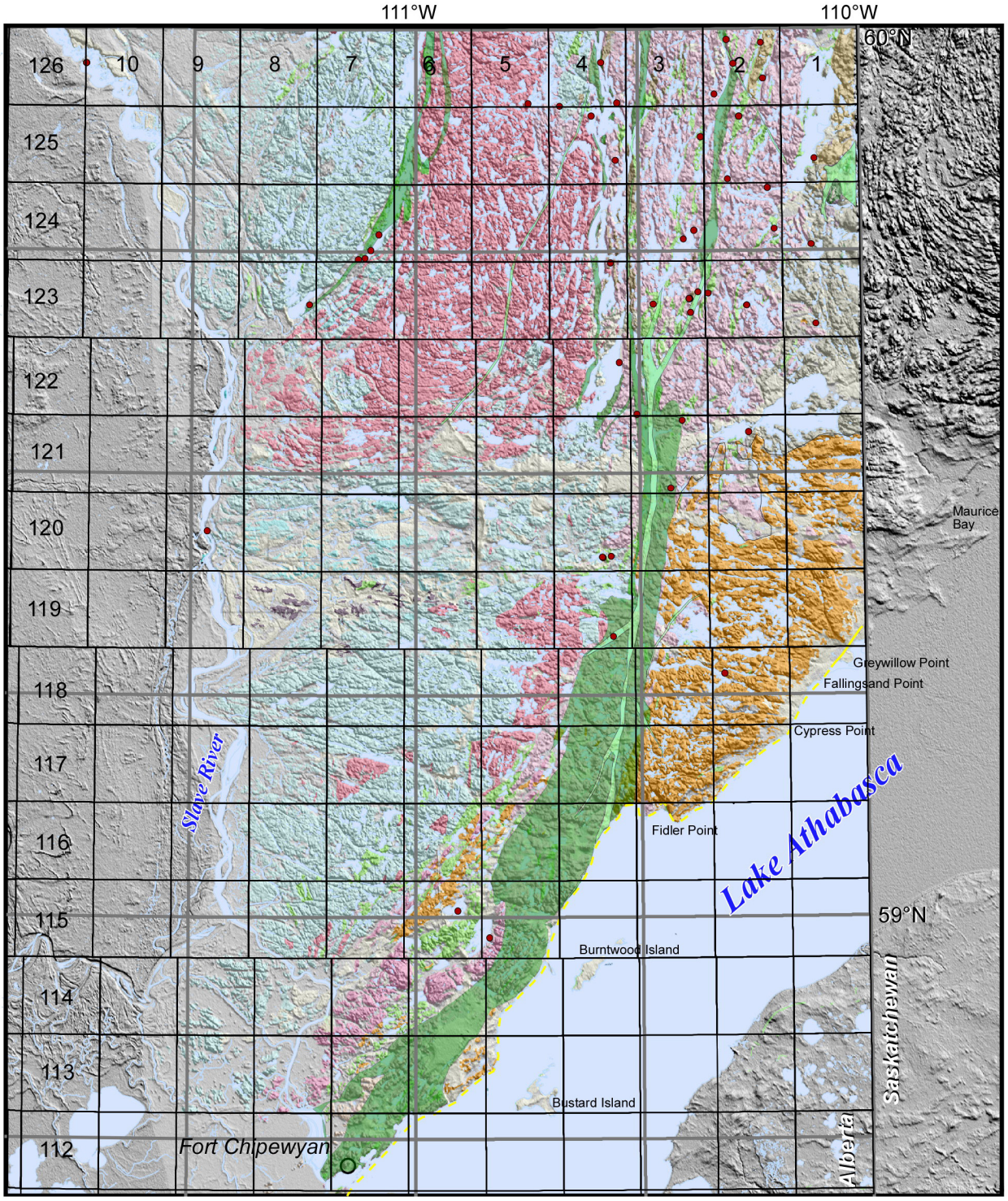


Figure 6. Mineral showings identified during geological mapping of the Alberta sheild carried out by the Geological Survey of Canada between 1992 and 1994 and compiled by McDonough et al. (1994a). See Figure 1 for legend.

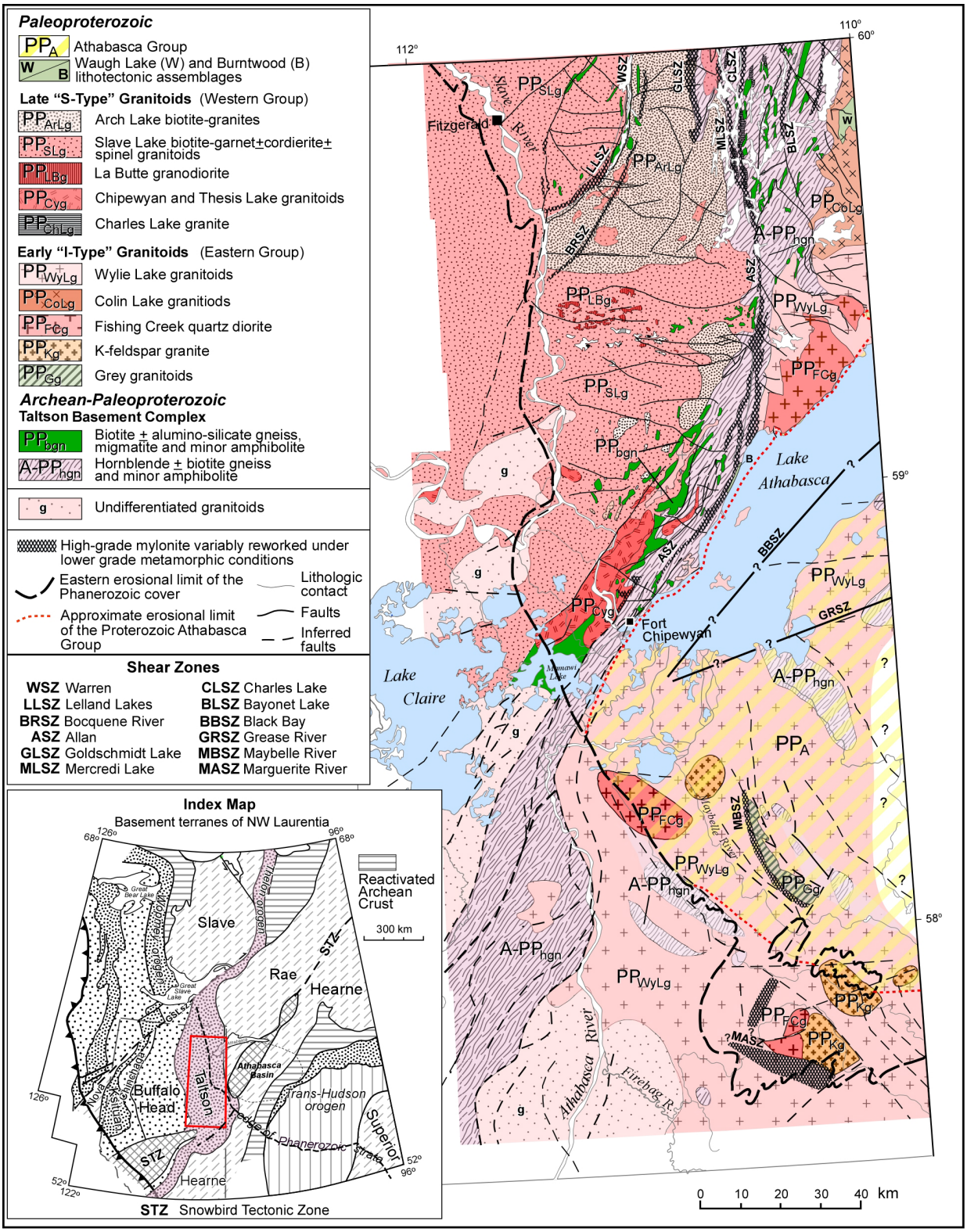


Figure 7. Sketch map of the basement geology in northeastern Alberta (modified after Pană et al., 2007). For an updated map of the Precambrian geology in northeastern Alberta see Pană (2009).

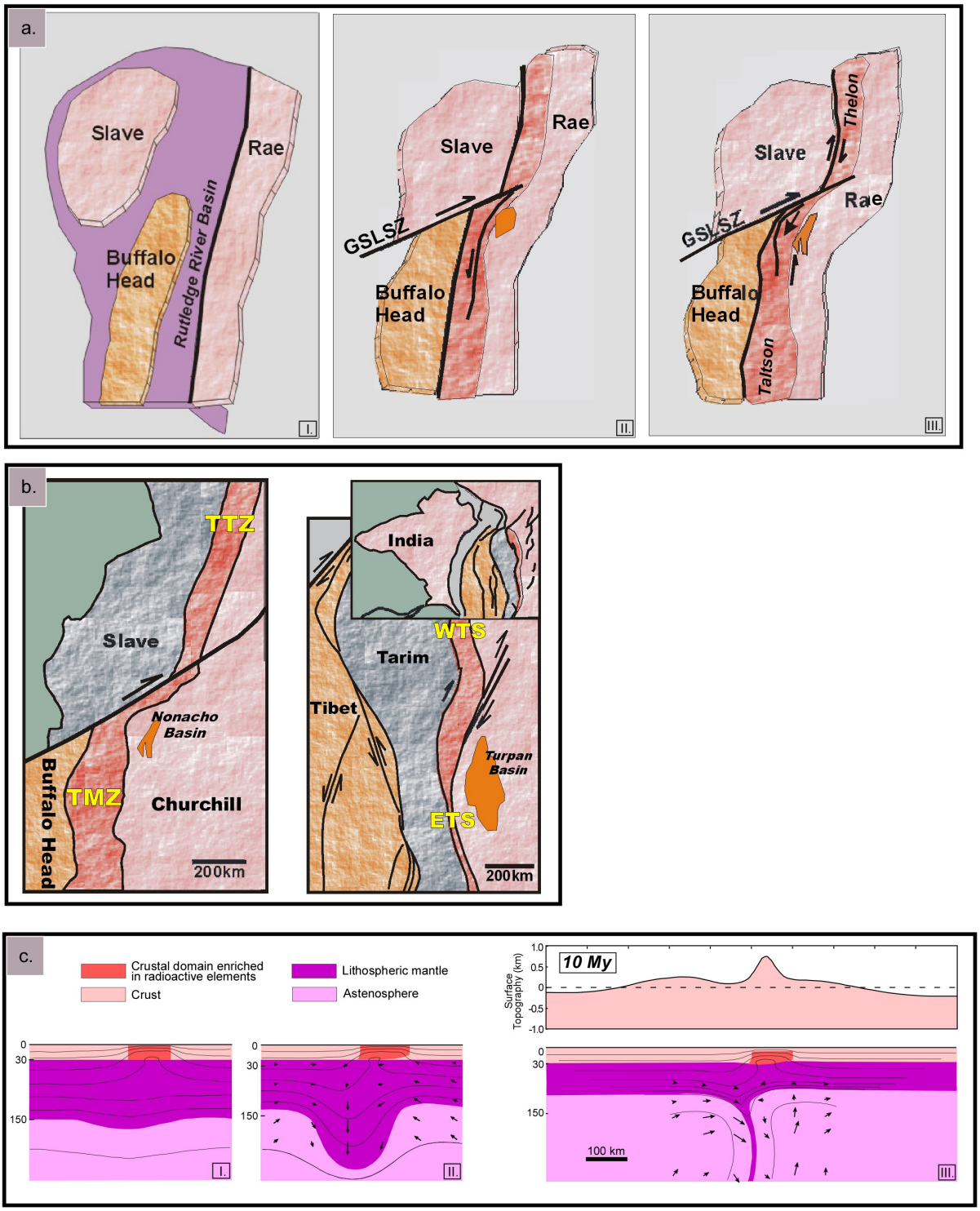


Figure 8. Existing regional tectonic models for the development of the Taltson magmatic zone: a) subduction/collision model, the Andean-Cordilleran analogy (e.g., Hoffman, 1988; Ross et al., 1991); b) intra-continental deformation triggered by subduction/collision at the western plate boundary, the Indo-Asian analogy (e.g., Chacko et al., 2000; De et al., 2000); TMZ-Taltson magmatic zone; TTZ-Thelon tectonic zone; WTS-West Tian Shan; ETS-East Tian Shan; c) intra-continental deformation triggered by mantle downwelling under a high radioactivity domain in the crust (Pană et al., 2007).

isotopic data revealed that the early granitoid suite of the TMZ lacks the mantle component apparent in Phanerozoic subduction-related granitoid rocks (Chacko et al., 2000; De et al., 2000). Instead, both early and late suites of the TMZ granitoid rocks in northeastern Alberta appear to have an intra-crustal origin. The Taltson-Thelon tectonomagmatic zone may have evolved in a plate-interior setting, with the Slave province acting as a secondary indenter, an ancient analogue of the Mesozoic Tian Shan belt in central Asia (Chacko et al., 2000; Figure 8b). However, both models invoke modern-style plate tectonics, which has become an increasingly controversial issue; several lines of evidence, including the first appearance of ophiolitic graveyards, blueschist facies metamorphic rocks and ultrahigh-pressure metamorphic terranes, indicate that the modern style of subduction tectonics began in the Neoproterozoic (Stern, 2005).

In the case of the Taltson-Thelon orogen, a subduction/collision tectonic evolution (Figure 8a) would require prograde metamorphic reactions through the kyanite field to high-pressure granulites and/or eclogites and/or blueschists along a clockwise pressure-temperature-time (PTt) path. Although plausible in the regional geological framework, the subduction/collision scenario conflicts with several lines of evidence (Pană et al., 2007), including the lack of: (1) high-pressure rocks or at least kyanite-bearing assemblages; (2) regionally consistent thrust zones; (3) remnants of the postulated oceanic crust; and (4) ca. 2.0 to 1.9 Ga juvenile material in the TMZ. The alternative Tian Shan analogy for the TMZ, which requires a Himalayan-type collision at the distant plate margin west of the TMZ, is inconsistent with the inferred contemporaneous evolution of the Wopmay Orogen west of the Slave indenter (Hoffman, 1988). The shortcomings and mutual incompatibilities of these tectonic models encouraged re-evaluation of existing data in light of large-scale, sub-continental mantle dynamics, which do not require subduction-related tectonomagmatic processes at, or distant from the TMZ (Pană et al., 2007; Figure 8c). Mantle downwelling and localized weakening of the crust, due to regions of anomalously high radioactive heat production, could have driven crustal thickening and resulted in an intra-continental orogen (Figure 8c). Thus, the Rae crust may have been heated above the stable, steady-state geotherm with crustal melting induced by anomalously high radioactive heat production and emplacement of early granitoid rocks. As a result of the regional field stress, the TMZ gradually evolved into a wide zone of oblique crustal stretching that triggered decompression melting and emplacement of late syntectonic granitoid rocks. Finally, the intracontinental Athabasca Basin initiated within crustal down-warping east of the TMZ.

4.1 Crystalline Basement of the Alberta Shield

The main area of the TMZ outcrop north of Lake Athabasca comprises a curving, linear body of metamorphic tectonites referred to as the Taltson basement complex (TBC), which is flanked by several distinct, moderately to strongly foliated granitoid plutons with minor TBC roof pendants (e.g., McDonough et al., 2000g; Figure 7). The TBC consists of a composite succession of Archean (3.2, 3.1, 2.6 Ga) and Early Proterozoic (2.4-2.1 Ga) metaplutonic gneisses with subordinate supracrustal gneisses and minor amphibolites (e.g., Godfrey, 1986a; McNicoll et al., 2000). Based on their petrology, age and position relative to the TBC (Godfrey, 1986a; Goff et al., 1986; Bostock et al., 1991; De et al., 2000; McDonough et al., 2000g; McNicoll et al., 2000), these granitoid rocks have been assigned on the Alberta sheild to two age groups: early 1.99 to 1.96 Ga weakly peraluminous to metaluminous granitoid rocks (I-type) east of the TBC, and late 1.955 to 1.928 Ga peraluminous suites (S-type) west of the TBC (Figure 7). The early TMZ plutons include (a) the ca. 1.971 Ga Colin Lake granodiorite to quartz diorite; (b) the ca. 1.963 Ga Wylie Lake suite of granodiorite, quartz diorite and quartz monzonite; and (c) the ca. 1.962 Ga to ca. 1.959 Ga Andrew Lake suite of granodiorite to diorite. The late plutons are characterized by abundant mafic clots of biotite, garnet, andalusite, hercynite and cordierite, and include the ca. 1.960 to ca. 1.934 Ga polyphase Slave monzogranites and the ca. 1.938 Ga Arch Lake quartz monzo to syenogranites. Several smaller, variously foliated plutons of uncertain geochemical affiliation are enclosed in the TBC, including Charles Lake granite suite with monazite metamorphic ages of ca. 1.933 to ca. 1.919 Ga, and the ca. 1.925 Ga Chipewyan and Thesis syenogranite to quartz monzonite.

High and medium-grade metamorphic tectonites of the Alberta sheild record transition from widespread granulite facies deformation to more localized deformation along major transcurrent shear zones during protracted syntectonic exhumation of the TMZ. Over time, strain was heterogeneously partitioned, migrated and concentrated in narrower belts during the evolution of shear zones through intermediate and shallow structural levels. From west to east, the following major northerly trending, high to low-grade shear zones straddle the Alberta-Northwest Territories border: Warren, Allan (Godfrey, 1958; Langenberg, 1983; Godfrey, 1986a) and Andrew Lake (McDonough et al., 2000g) shear zones. The traditional names of the Allan and Warren shear zones are referenced here, as initially introduced by Godfrey (1958), whereas the alternative names introduced in the 1990s (e.g., McDonough et al., 2000g) are used only for splays located in the area specified in the geographic component of the name; other splays have been named by Pană et al. (2007). Thus, the Warren shear zone consists of two sub-parallel, curvilinear, 50 to 500-metre wide belts of subvertical mylonites: the northwestern Leland Lakes and the southeastern Bocquene River shear zones (Figure 7). The Allan shear zone constitutes a braided system of anastomosing subvertical 0.5 to 3-km wide splays of ductile mylonites. From west to east, these splays are the Goldschmidt Lake, Mercredi Lake, Charles Lake and Bayonet Lake shear zones (Figure 7). While the Mercredi Lake and Charles Lake shear zones splay northward from the main Allen shear zone, the Goldschmidt Lake and Bayonet Lake shear zones are separated from the main branch by rocks with different strain characteristics. The crosscutting relationships between shear zones and granitoids are very complex (e.g., McDonough et al., 2000g).

Two low-grade lithotectonic assemblages have been interpreted to represent sediments affected by low-grade prograde metamorphism (e.g., Godfrey, 1986a): the Burntwood Group near the northern shoreline of Lake Athabasca and Waugh Lake Group, east of Andrew Lake. Preliminary field, isotope and microscopic observations indicate that low-grade mylonite derived from adjacent granitoid and gneiss is interlayered with variably sheared layers that appear to have sedimentary protoliths and pods of basalt and/or andesite. The Burntwood and Waugh Lake successions may represent remnants of composite lithotectonic assemblages formed within the upper structural levels of crustal scale shear zones by tectonic interlayering of retrogressed granitoid gneiss wallrock with local sedimentary cover and minor igneous plugs during the late stages of TMZ syntectonic exhumation (Pana et al., 2007).

4.2 The Athabasca Group

4.2.1 Stratigraphy

The Athabasca Group consists of at least 2.1 km of predominantly fluviatile clastic deposits, with some lacustrine and possible marine sediments confined to the uppermost sequences (e.g., Ramaekers, 1990, 2003; Collier, 2005). The remnants of the Athabasca Group define two partly overlapping depositional basins, which have distinct polarities and tectonic regimes. Seven basin-filling rhythms or third-order sequences are defined as laterally extensive, upward-fining packages bound by unconformities, or picked based on selected sedimentological parameters on lithologs where unconformities are difficult to directly identify in drillcore (Table 2 and Figure 9). They largely correspond to the lithostratigraphic units of Ramaekers (2003) and, from base to top, consist of the following units (Table 2):

The coarse clastics of the Fair Point Sequence are confined to the western portion of the Athabasca Basin and define the Jackfish sub-basin. Sandstone and conglomerate strata that locally occur along the northern shore of Lake Athabasca belong to the Fair Point Sequence. Above Fair Point is a highly erosive unconformity boundary containing localized paleosols.

The clastics of the overlying successor basin are markedly finer. The basal Shea Creek and Lower Manitou Falls sequences are preserved south and east of the Jackfish sub-basin, whereas the overlying Upper Manitou Falls Sequence extended into the area of the former Jackfish sub-basin. These

Table 2. Summary of the stratigraphic sequences defined in the Alberta portion of the Athabasca Group (Collier, 2005)

Stratigraphic Sequence	Maximum Thickness	Facies Association	Depositional Environment
Locker Lake-Carswell	600 m	Mudstone (abundant sandstone) – Douglas Fm	Lacustrine
		Clean fine-grained sandstone – Otherside Fm.	Fluvial
		Granule-bearing medium-grained sandstone – Otherside Fm.	
		Pebbly, medium-grained sandstone with minor conglomerate	
Wolverine Point	315 m	Clay-rich, medium-grained sandstone	
		Mudstone (abundant sandstone)	Lacustrine
		Fine-grained sandstone (abundant mudstone)	Fluvial
		Fine-grained sandstone (little or no mudstone)	
		Granule/pebbly medium-grained sandstone	
Lazenby Lake	285 m	Clay intraclast-rich, medium-grained sandstone	
		Granule-rich, medium-grained sandstone	
		Fine- to medium-grained sandstone (little or no mudstone)	
		Fine- to medium-grained sandstone (common mudstone)	
		Pebbly, medium-grained sandstone	
Upper Manitou Falls	250 m	Clean, medium-grained sandstone (frequent clay clasts)	
		Clean, medium-grained sandstone (few or no clay clasts)	
		Granule/pebble-bearing, medium-grained sandstone	
		Conglomeratic medium-grained sandstone	
		Basal lithologies (above basement)	
Lower Manitou Falls	99 m	Clean, medium-grained sandstone (few or no clay clasts)	
		Pebbly to conglomeratic medium-grained sandstone	
		Basal lithologies (above basement)	
Shea Creek	97 m	Low-angle, cross-bedded sandstone	
		Trough cross-bedded sandstone	
		Basal lithologies (above basement)	
Major Unconformity			
Fair Point	300 m	Pebbly, medium to coarse-grained sandstone	Fluvial
		Conglomeratic coarse-grained sandstone and conglomerate	
		Basal lithologies (above basement)	

sequences are entirely fluvial and were probably restricted close to the current margins of the remnant Athabasca Basin. Their coarsening-upward stacking pattern suggests a regression under relatively low accommodation rates.

The overlying Lazenby Lake, Wolverine Point and Locker Lake-Carswell sequences were originally more widespread then the underlying sequences. Their upward-fining stacking pattern indicates back-stepping (transgression) under relatively high rates of accommodation. These sequences thicken upward and evolve from entirely fluvial to fluvial-lacustrine to fluvial-lacustrine-marine. The Lazenby Lake and Wolverine Point sequences are widespread over large portions of the central and western portions of the Athabasca Basin. The Locker Lake and Otherside formations occur mostly in the central portion of the basin in Saskatchewan and have limited extent in Alberta (Figure 9). The Douglas and Carswell formations are restricted to the periphery of the 356-515 Ma old Carswell meteorite structure in Saskatchewan (Bell, 1985).

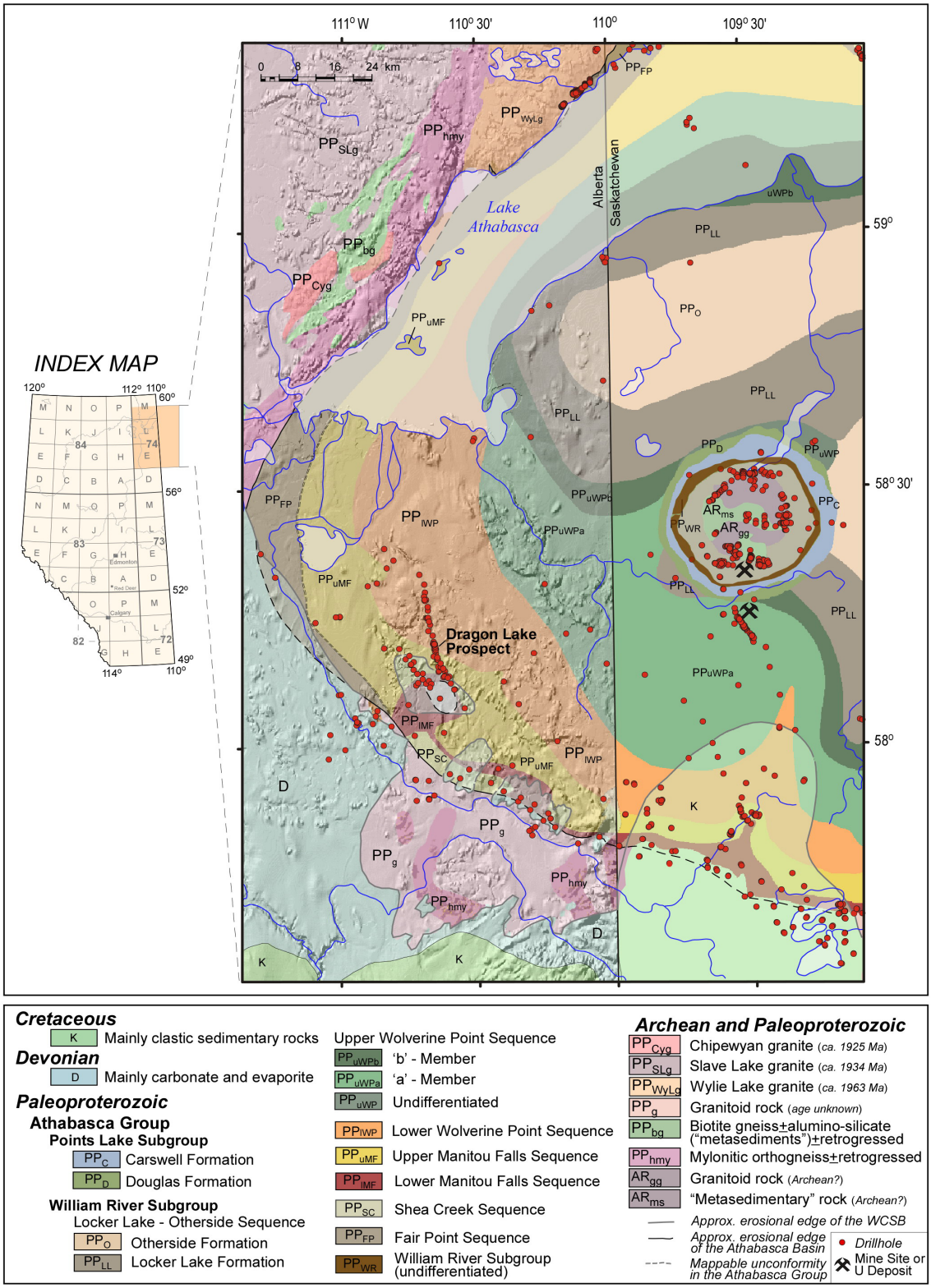


Figure 9. Map of the Athabasca Group in eastern Alberta and western Saskatchewan, adapted from Collier (2005). Colours in the fused geological map-digital elevation model in Alberta appear less intense than in legend. WCSB - Western Canada Sedimentary Basin. For an updated map of the Precambrian geology in northeastern Alberta see Pană (2009).

Rapid changes in sequence thickness and basal lithology may be linked to syn-depositional faulting. Detailed stratigraphy of the Athabasca Group may be used to predict where fault zones occur in the western Athabasca Basin and, therefore, indicate potential for uranium mineralized zones (Ramaekers, 2003; Post, 2004; Collier, 2005; Ramaekers et al., 2007).

4.2.2 Age of the Athabasca Group

The age of the Athabasca Group was inferred to be older than 1550 Ma based on a paleomagnetic study of the Athabasca Group (Fahrig et al., 1978), older than 1632±32 Ma based on a Rb-Sr isochron date obtained from altered sub-Athabasca gneiss (Fahrig and Loveridge, 1981), and to be ca. 1350±50 Ma, or 1.43±0.03 Ga based on Rb-Sr isochron dates of Ramaekers and Dunn (1977) and Armstrong and Ramaekers (1985), respectively. Recent detrital and diagenetic mineral geochronology of stratigraphic sequences above the Athabasca unconformity, linked with existing geochronology of the uranium deposits, provided new constraints on the age of the Athabasca Group. A maximum age for the initiation of sedimentation in the Athabasca Basin of 1740 to 1730 Ma was estimated based on ages of early diagenetic phosphatic material in possibly correlative strata from the Thelon Basin (Miller et al., 1989; Rainbird et al., 2007). However, metamorphic ages on titanite as young as 1750 Ma in basement rocks (Orrell et al., 1999) and K/Ar and $^{40}Ar/^{39}Ar$ cooling ages on biotite and feldspar ranging from ca. 1800 to ca. 1700 Ma (Baasgaard and Godfrey, 1972; Plint and McDonough, 1995), indicate the basement units that currently underlie the oldest strata deposited in the Athabasca Basin, the Fair Point Formation, were still at a depth of about 10 km at ca. 1700 Ma. Therefore, we suggest the Athabasca Group may be younger than 1.7 Ga because this 10 km thickness of crust would have had to have been uplifted and eroded prior to the Athabasca Group deposition. The upper ages of the Athabasca Group are weakly constrained. Diagenetic fluorapatite in Fair Point and Wolverine Point formations yielded uncertain uranium-lead (U-Pb) dates of more than 1650 to 1700 Ma (Cumming et al., 1987). Tuffaceous units in the Wolverine Point Formation have been U-Pb dated at ca. 1644±13 Ma (Rainbird et al., 2007). Organic-rich shale of the Douglas Formation appears to be about 100 Ma younger (Creaser and Stasiuk, 2007). Therefore, these somewhat conflicting data indicate the Athabasca Group was deposited over a time interval of 50 - 200 million years, between about 1740 Ma at the earliest and 1550 Ma at the latest.

5 Local Geology of the Previously Explored Properties

5.1 Permits 244, 189 and 190

Near the Alberta-Saskatchewan border, the area of former mineral permits 244, 189 and 190 is underlain mostly by granitoids of the Wylie Lake pluton and subordinately by the Fair Point Formation of the Athabasca Group (Kilby and Walker, 1979; Godfrey, 1980a; Figure 10). According to Godfrey's (1986a) map, shield rocks in this area include:

1) Wylie Lake granodiorite with minor quartz diorite; generally dark greenish or brownish red; may appear finely mottled; medium-grained, typically equigranular except for rare pink feldspar megacrysts (15 mm) in a feldspar, quartz, biotite matrix; typically poorly foliated to massive;

2) Fishing Creek granitoid appears to be a distinct phase of quartz diorite to granodiorite within the Wylie Lake pluton. Its overall colour is medium grey and mottled greyish white on a medium to dark grey background in hand specimen; typically almost megacrystic white to grey to pale green feldspars 5 to 10 mm long in a greenish grey matrix of feldspar, quartz and biotite; locally medium-grained equigranular; typically poorly foliated, but well foliated gneissic or massive varieties are also known locally. Almandine and/or hornblende are widely distributed in the Fishing Creek quartz diorite.

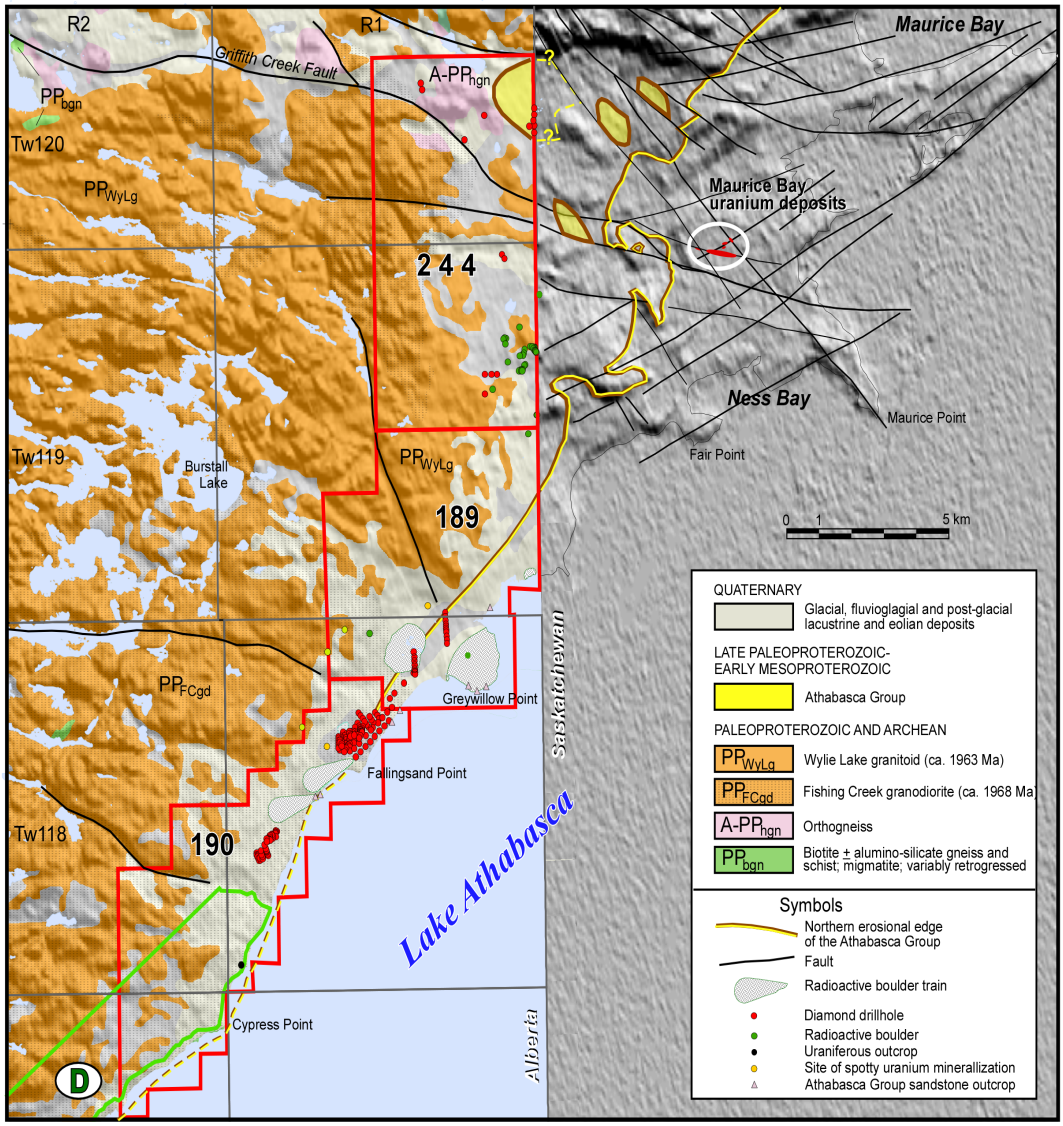


Figure 10. Geological map in the area of former Permits 244, 189 and 190 compiled from Godfrey (1986a), Harper (1996) and McDonough et al., (2000c); D - Fidler-Greywillow Wildland.

Other common phases in the Wylie Lake pluton include a grey-white mottled granodiorite to granite and quartz diorite with feldspar megacrysts 20 to 25 mm long and a greenish or brownish, essentially equigranular granodiorite. All granitoids and granitoid gneisses include mappable discontinuous lenses and bands of a quartz-biotite matrix with feldspar megacrysts, and subordinate schlieren of mafic minerals (mainly biotite), or more micaceous and/or quartzitic layers with cordierite, almandine and rarely hornblende. Many of these lenses and bands have been interpreted as metasediments; however, most of these layers are too small to be mapped. In the northern part of Permit 244, pink biotite (rarely hornblende) granite gneiss grades into migmatite, and includes pods of pegmatite and minor amphibolite. Mafic minerals are commonly retrogressed to chlorite. This rock type has been assigned to Taltson basement complex (McDonough et al., 2000c, d). The granitoids are variably overprinted by a generally steeply dipping (65°-90°) foliation and grade into granite gneisses. The dominant foliation trends northwesterly within Permit 244 and northeasterly within permits 189 and 190. In areas of

pegmatite veining, tight isoclinal folds and dismembered fold closures record polyphase deformation at intermediate crustal levels (Figure 11). Granitoids and the subordinate metasedimentary rocks are often retrogressed, with biotite, hornblende or garnet partly altered to chlorite and veinlets of epidote. Belts of strain concentration and retrogression (low-grade mylonites) are dark coloured, with white to grey anhedral feldspar porphyroclasts and euhedral porphyroblasts 10 to 15 mm long within an aphanitic to medium-grained matrix (Godfrey, 1986a). The mylonites are cut by minor aplite and pegmatite and are occasionally brecciated with quartz filling and quartz-lined vugs, which indicate a protracted deformation history at shallow structural levels. To the south, the area of the former Permits 189 and 190 includes a narrow and poorly exposed belt of Athabasca sandstone along the Lake Athabasca shore. Two small outcrops of Athabasca sandstone are along the southeastern shore of Greywillow Peninsula and approximately 1.8 km south along the shoreline. These medium-grained sandstones, with gritty bands and well-rounded quartzite pebbles 2 to 6 cm in diameter are typically hematite red to purple buff, flaggy to rubbly bedded. They are underlain in part by highly altered basement regolith material with intense hematite stains, numerous fractures and minor quartz veinlets. From the shore of Lake Athabasca inland, the area is covered by a 1 to 3 km wide belt of Quaternary materials, primarily sandy raised beaches (Bednarsky, 1999).

Two east-southeasterly trending faults, which were mapped on the Shield (Godfrey, 1980a) project within Permit 190, north and south of Fallingsand Point, respectively, and a third one which trends south-southeast projects within Permit 189 along the eastern part of Greywillow Peninsula. As well, several southwest trending faults that were mapped in Saskatchewan immediately across the Alberta-Saskatchewan border (Harper, 1996), project within Permit 189. The two south-southeast trending faults that project under Quaternary sand toward Fallingsand Point are subparallel with the Griffith Creek fault in Saskatchewan. Less than 10 kilometres from the Alberta border, the intersection of Griffith Creek fault, with one of many southwesterly trending faults, has been a focus for uranium mineralization at and near Maurice Bay (Harper, 1996).

According to Lehnert-Thiel (1975), uranium occurrences (as evidenced by uranophane yellow bloom and high radioactivity) have been noted in several places in this area within the high-grade metasedimentary rocks. As well, pyrite is commonly found within the metasedimentary and amphibolitic rocks, with minor amounts locally in quartz veins, granite and granite gneisses. Molybdenite and/or its yellow oxidation product (powellite) have been noted in minor amounts in rocks of the metasedimentary group. A large number of Athabasca Group sandstone and conglomerate float boulders were found in the gridded area of the permit. While most had low background radioactivity, some had anomalously high radioactive counts (SPP2N scintillometer), amongst these

1) a strongly hematitic quartz pebble conglomerate with a quartz-rich matrix resembling Tazin Group rocks, but with high quartz content of the matrix typical for the Athabasca Group;

2) a pinkish weathering medium-grained Athabasca Group quartzite with minor secondary uranium minerals; and

3) a pink weathering, garnet-bearing, chlorite gneiss boulder with up to 1400 cps, which probably originated in a retrogressive shear zone.

The geochemical characteristics of the boulders suggest an Alberta source in addition to the Maurice Bay source (Lehnert-Thiel, 1975). Exploration work carried out in the area of permits 244, 189 and 190 is summarized in Appendix 1, Tables A1 to A5.

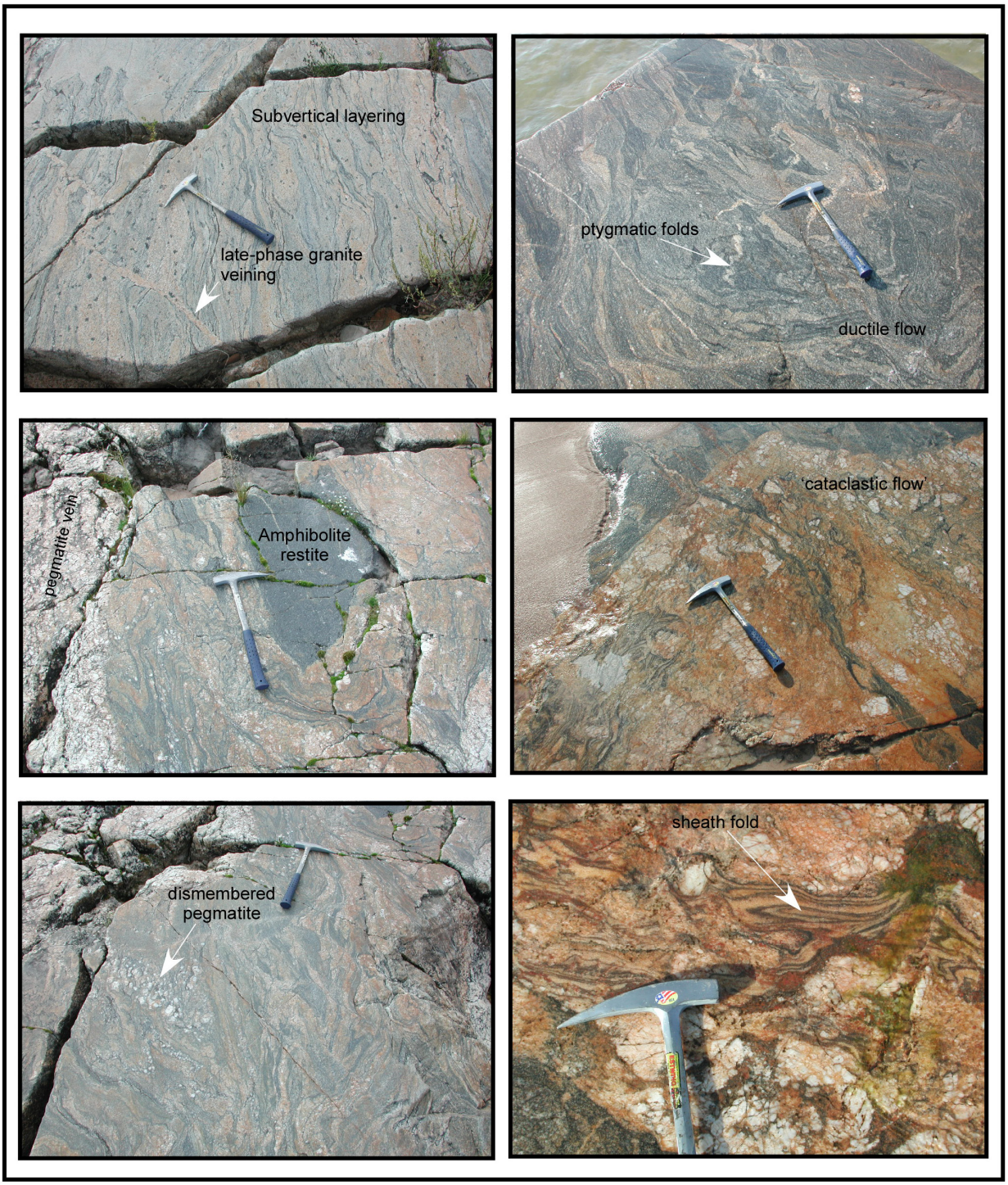


Figure 11. Concurrent polyphase deformation and migmatization of a mafic protolith along the northern shore of Lake Athabasca; mafic rocks are invaded by multiple generations of granite and pegmatite during ductile flow in competent finer-grained layers and 'cataclastic flow' in less competent coarse-grained pegmatite; deformation resulted in rootless folds, sheath folds, pinch-and-swell structures and ovoidal nodules of mafic rocks with massive gabbroic and eclogite-like textures or foliated amphibolitic textures. Relatively high radioactivity (up to 1000 cps) was recorded mainly at the periphery of pegmatite veins.

5.2 Permits 125, 126 and 137

In the 1970s, a property consisting of former Permits 125, 126 and 137 was located along the southern segment of the Allan shear zone, where it nears the Lake Athabasca shoreline and where structural trends take a major swing from a southerly to a southwesterly trend (Figure 12). The western portion of the property is underlain by the Taltson basement complex overprinted by Allan shear zone. Elongated hills and lozenge-shaped depressions follow individual shear zones and faults, which parallel the subvertical foliation and layering in the Taltson basement complex. The eastern portion of the property mostly encompasses Wylie Lake and Fishing Creek granitoids. A small area northwest of Fidler Point is underlain by the Athabasca Group.

Taltson basement complex includes pink to reddish biotite granitoid gneiss with quartz-feldspar bands interlayered with mafic-rich bands of biotite, rarely hornblende, and subordinate metasedimentary rocks (Godfrey, 1984). Large areas are migmatitic with minor lenses, pods and bands of metasedimentary rocks, pegmatite, or amphibolite. Amphibolites range from massive ortho-amphibolite along the western shoreline of Fidler Point, to well-banded feldspathic biotite amphibolite layers along the western shoreline of Lapworth Point. The orthogneisses are commonly well banded, but locally they may be poorly banded with nearly massive leucocratic phases and with pods of Wylie Lake granite. Taltson basement complex recorded granulite to amphibolite grade metamorphic conditions with local retrogression to greenschist grade. Most orthogneisses mapped by Godfrey (1986a) have been reinterpreted by McDonough et al. (2000c, d, e, f) as high-grade mylonites, whereas the "recrystallized cataclastic rocks" originally mapped by Godfrey (1986a) as Allan fault have been remapped as continuous and partly concordant belts of low-grade mylonites, up to 1 km long by 100 m wide (McDonough et al., 2000c, d, e, f). The low-grade rocks have been assigned igneous or metasedimentary protoliths based on their light or dark colour, respectively (Godfrey, 1984). Thus, chlorite, sericite schists with feldspar and quartz porphyroclasts in a finely banded, aphanitic matrix were interpreted as blastomylonites derived from the adjacent gneisses. Whereas along strike to the southwest on the shore of Lake Athabasca a 200 m by 2 km-long wide belt of chloritic phyllonites with intercalations of variously strained quarto-feldspathic layers are interpreted as sediments affected by prograde metamorphosed under low-grade conditions and assigned to the Burntwood Group (Godfrey, 1980b; 1984) or the Athabasca Group (McDonough and McNicoll, 1997).

Near Fidler Point, heterolithic and poorly sorted conglomerate (fanglomerate), which tends to fine up section into a pebble and fragment sandstone and clay matrix beds are assigned to the Fair Point Formation of the Athabasca Group. The original unconformity between the Fidler Point Formation and the crystalline basement is overprinted by a steeply dipping (75° to 80°) north-northwesterly fault with normal and left lateral displacement (Dick, 1999). This fault continues inland for a few kilometres and appears to join one of the greenschist mylonite belts of the Allan shear zone (Figure 12). Variably gneissified biotite granites, pervasively laced with red and white pegmatite segregation lenses 2 to 5 m in length, crop out in the footwall along the fault. Where observed, the contact is not faulted, but the units are sheared along the contact and overprinted by local north-trending fracture cleavage (Figure 13). The bottom conglomerate overlies a hematized, massive sandstone bed in contact with the regolith (Figure 14). The regolith, up to 12 m thick, appears as a continuum from intensely hematized granite to a coarse, friable hematite-quartz-clay altered platy rock to a sheared, hematite-rich clay that is speckled with quartz fragments from altered pegmatite veins.

Granitoids altered along faults have a very similar appearance to the 'regolith'-type alteration. Thus, along a northeasterly trending fault, a mylonitized pegmatitic granite was reduced to a limonite-hematite fault gauge with relic quartz fragments, and granite is locally altered to friable hematite-quartz-clay-carbonate (Dick, 1999). Exploration work on this property and the exploration results are summarized in Appendix 1, Tables A6 and A7.

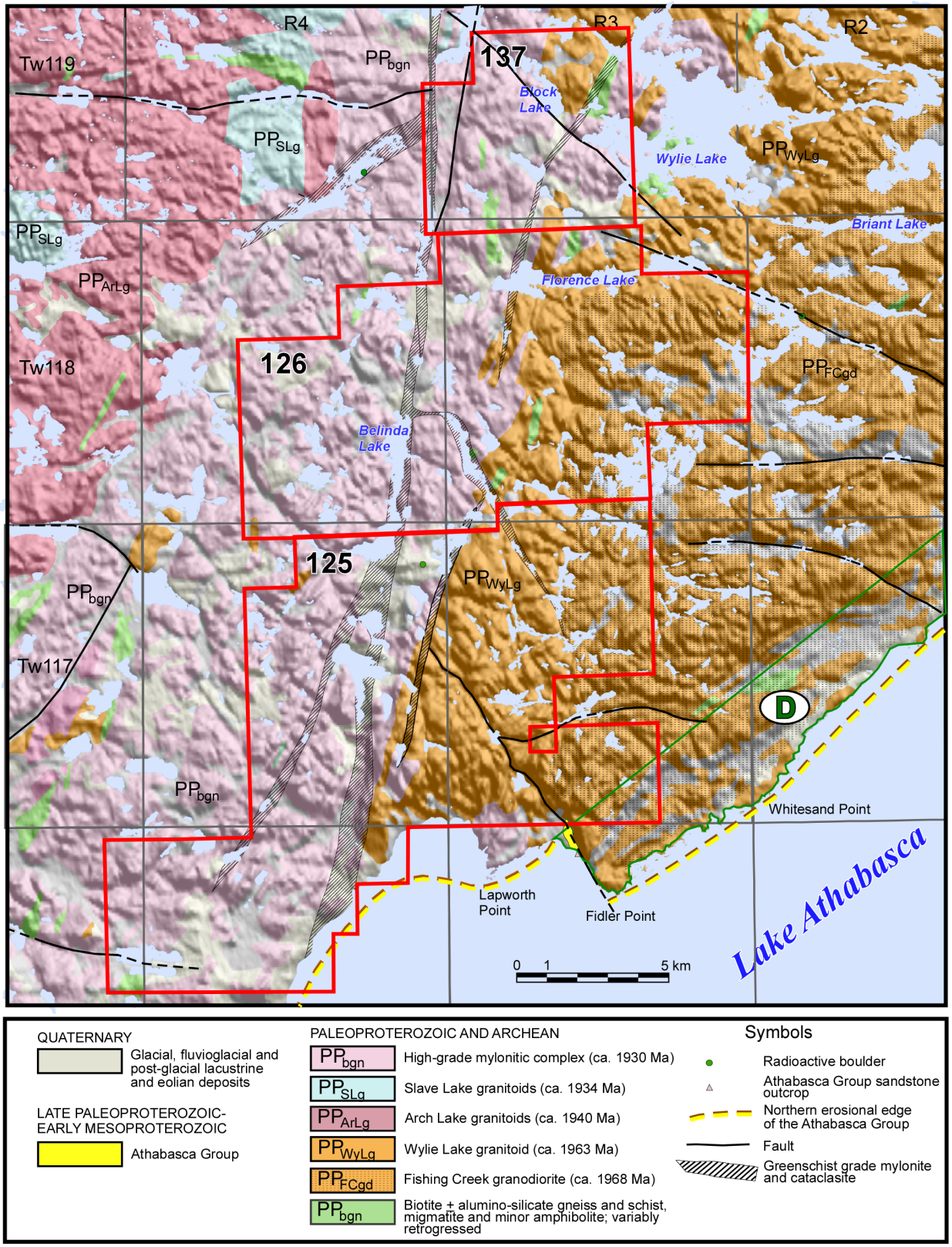


Figure 12. Geological map in the area of former Permits 125, 126 and 137 compiled from Godfrey (1986a) and McDonough et al. (2000c,d,e and f); D - Fidler-Greywillow Wildland.

Figure 13. Subvertical fracture cleavage overprinting conglomeratic sandstone of the Fair Point Formation along the faulted Athabasca unconformity on the western side of Fidler Point promontory (view to the south).

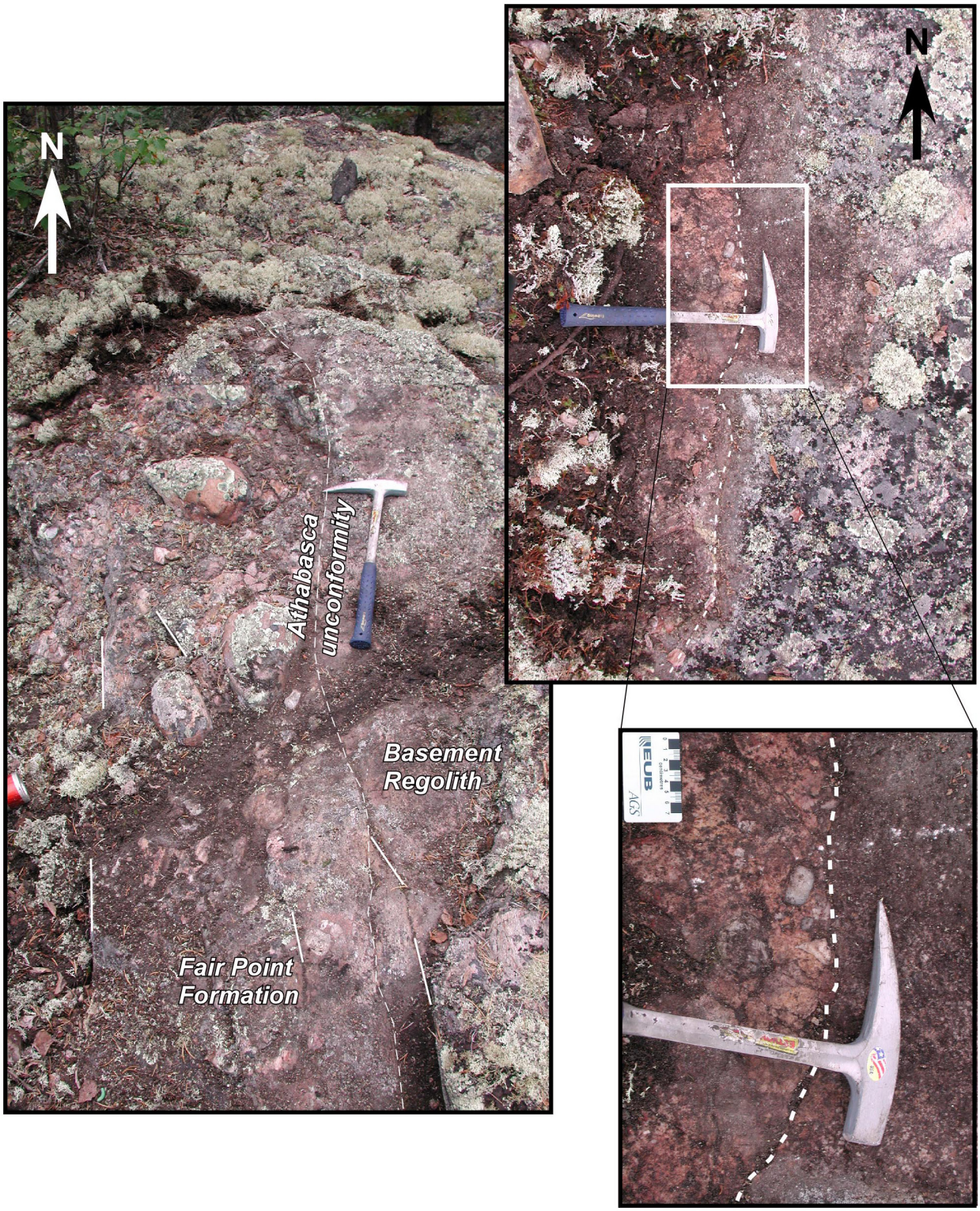


Figure 14. Vertical contact of Fair Point Formation with the basement regolith at Fidler Point. The Athabasca unconformity (dashed line) appears overprinted by fracture cleavage (solid lines) along a northerly trending local fault zone with the western block down-dropped.

5.3 Permits 193 and 194

The area of former permits 193 and 194 encompasses mostly orthogneisses of the Taltson basement complex near Sand Point and the Fishing Creek quartz diorite with subordinate biotite granite gneiss and metasedimentary belts toward Shelter Point (Figure 15). Multiple large-scale northeasterly faults and small scale northwesterly trending faults run through the region. The property area is extensively covered by Quaternary materials, mainly sand that may mask Athabasca Group bedrock north of Shelter Point (Wilson, 1986). In some places, extensive boulder fields reportedly included isolated radioactive boulders (Figures 16 and 17). Sandstone of the Athabasca Group is exposed on Burntwood Island, approximately 4 km east of Sand Point (MacMahon, 1977; Lehnert-Thiel et al., 1978a, b).

Permit 193 is underlain mostly by biotite granite gneiss with minor layers of metasedimentary rocks. The eastern portion of the granite gneisses, affected by the southwesterly trending Allan shear zone, consists of flaser gneiss and porphyroblastic augen gneiss grading into blastomylonite, mylonite, ultramylonite and cataclasite (Figure 18). Compositional layering extends over a range of scales from hand specimen, to outcrop, to belts several miles long. In a small area toward the northeastern corner of the permit, low-grade metamorphic rocks have been assigned to the "Burntwood Group" (Godfrey, 1980b; 1984), which is well exposed to the northeast outside the property, along the shore of Lake Athabasca (Figure 19). Along the lakeshore, these rocks were initially assigned to the Martin Formation (Lehnert-Thiel, 1975), Thluicho Lake Group (MacMahon, 1977) and later to the Athabasca Group (McDonough and McNicoll, 1997).

The granite gneiss along the shoreline is generally mylonitic, well banded with pink to reddish quartz-feldspar bands with up to 2 cm long white to pink feldspar porphyroclasts, interlayered with dark green bands of variably chloritized hornblende and/or biotite, or with finely banded, cataclastic, aphanitic matrix. Locally in areas of weaker mylonitic overprint, the protoliths can be identified as orthogneisses derived from granite, quartz monzonite, granodiorite, quartz diorite and monzodiorite (Godfrey, 1986a). Large areas are migmatitic with minor lenses, pods and bands of pegmatite, amphibolite or metasedimentary rocks. In the northern portion of Permit 193, the Burntwood lithotectonic assemblage is exposed along the northern shore of Lake Athabasca as a northeasterly trending, 100 m by 3 km-long belt of steeply dipping greenschist to subgreenschist facies rocks. It includes banded chlorite-sericite schist interlayered with hematite-cemented granular rocks and other variously strained quartzofeldspathic rocks, commonly invaded by quartz-hematite stockwork. To the northwest, it is bounded by amphibolite facies mylonites of the Allan shear zone, while its southeastern boundary is submersed beneath Lake Athabasca. The authors of this report consider this sequence unrelated to the Athabasca Group as proposed by McDonough and McNicoll (1997) and recognize that it records high intensity of strain. While the second author (R. Olson) firmly believes the protolith of the Burntwood lithotectonic assemblage is of sedimentary origin, the first author (D. Pană) suspects it represents the shallow structural level of a fault zone with most, if not all, rock types being directly derived from adjacent Taltson orthogneiss through polyphase deformation, strain partitioning and retrogression. Considering the critical role of permeable fault zones in the development of Athabasca unconformity-related uranium deposits (Pană, 2007), further detailed examination of the Burntwood lithotectonic assemblages, and in particular its possible southwesterly extension, is warranted.

Toward Shelter Point, the dominant rocks within Permit 194 are Wylie Lake granitoids (Godfrey, 1986a) and an outlier of Athabasca Group bedrock, which was tentatively interpreted north of Shelter Point under a large area covered by sand (Wilson, 1986; Figure 15).

Exploration work and positive results are summarized in Appendix 1, Tables A8, A9 and A10.

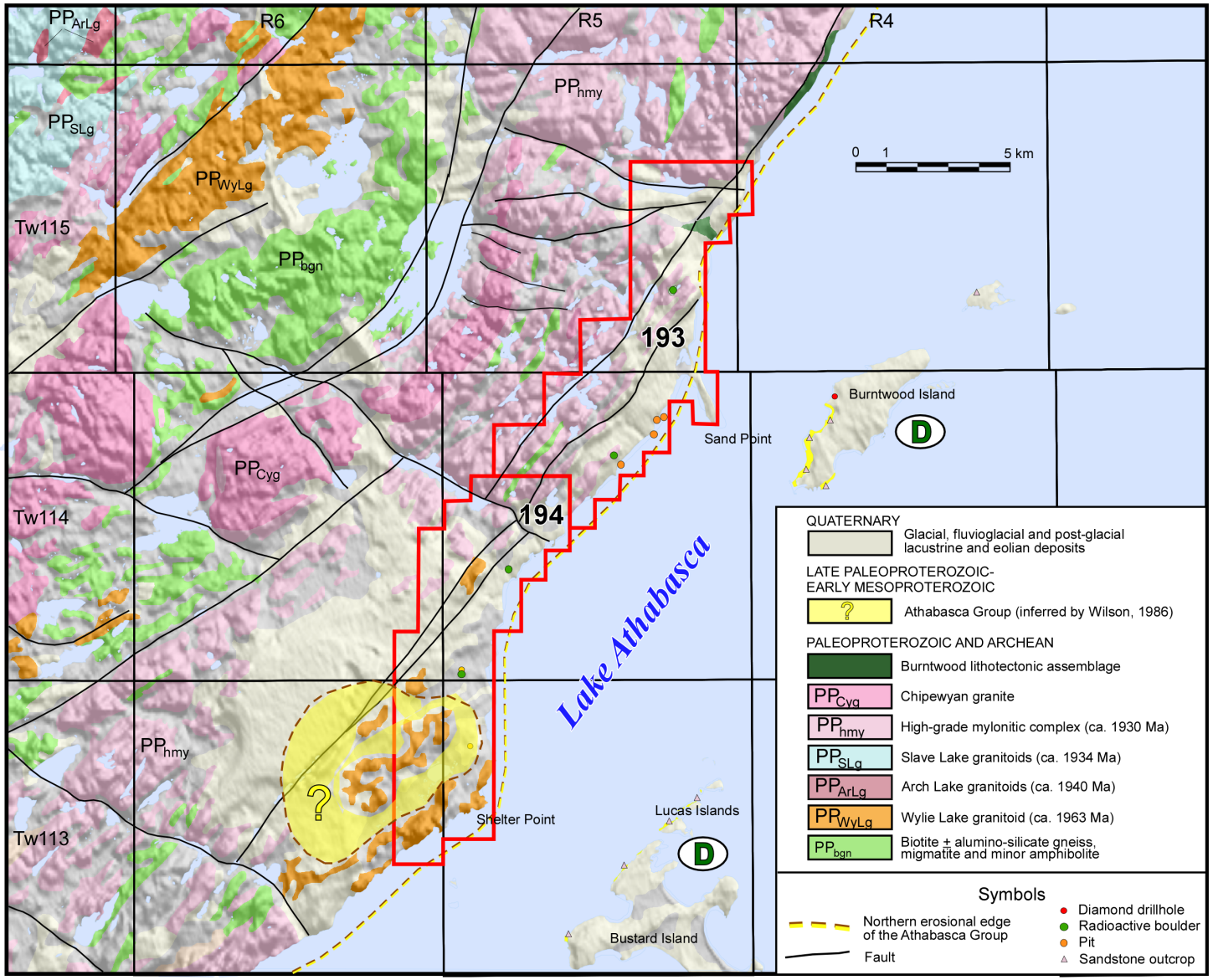


Figure 15. Geological map in the area of former Permits 193 and 194 compiled from Godfrey (1986a) and McDonough et al., (2000e); D - Fidler-Greywillow Wildland.

Figure 16. Boulder field north of Shelter Point, which reportedly included a few boulders with anomalous radioactivity (Lehnert-Thiel et al., 1978a).

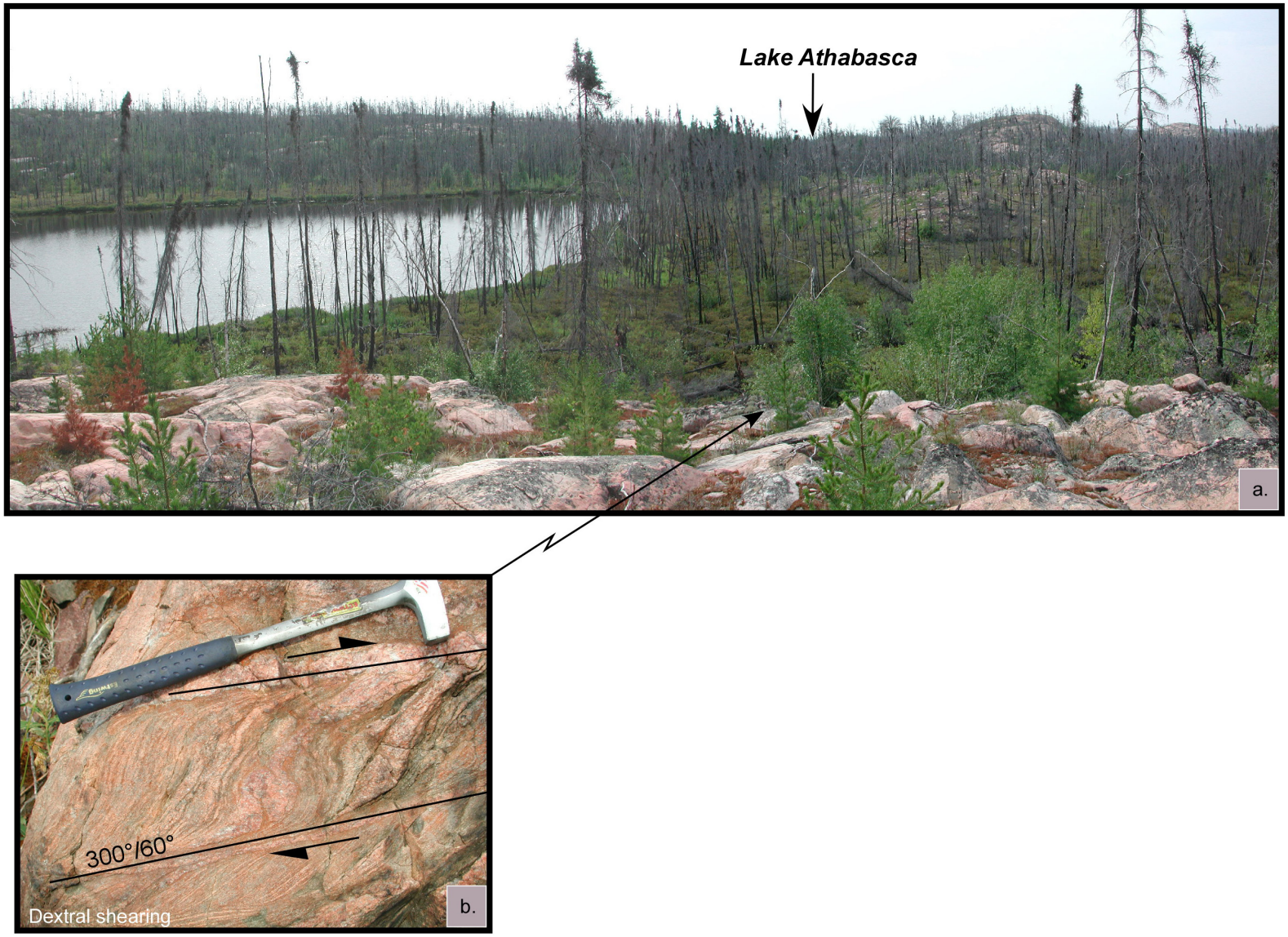


Figure 17. Boulder field near Sandy Point included an anomalously radioactive boulder (cf. Lehnert-Thiel and Kretschmar, 1976); a) panoramic view to southwest; b) detail: synkinematic intrusion of granite veins in a quartzo-feldspathic gneiss of the Taltson basement complex.

Figure 18. Strain at different structural levels within Charles Lake (Allan) shear zone; a) augen gneiss derived from phenocrystic granitoid, a few tens of metres inland from Sandy Point (granite and pegmatite layers show up to 600 cps); b) augen gneiss overprinted by dextral displacement slikensides, east side of airport road, Fort Chipewyan.

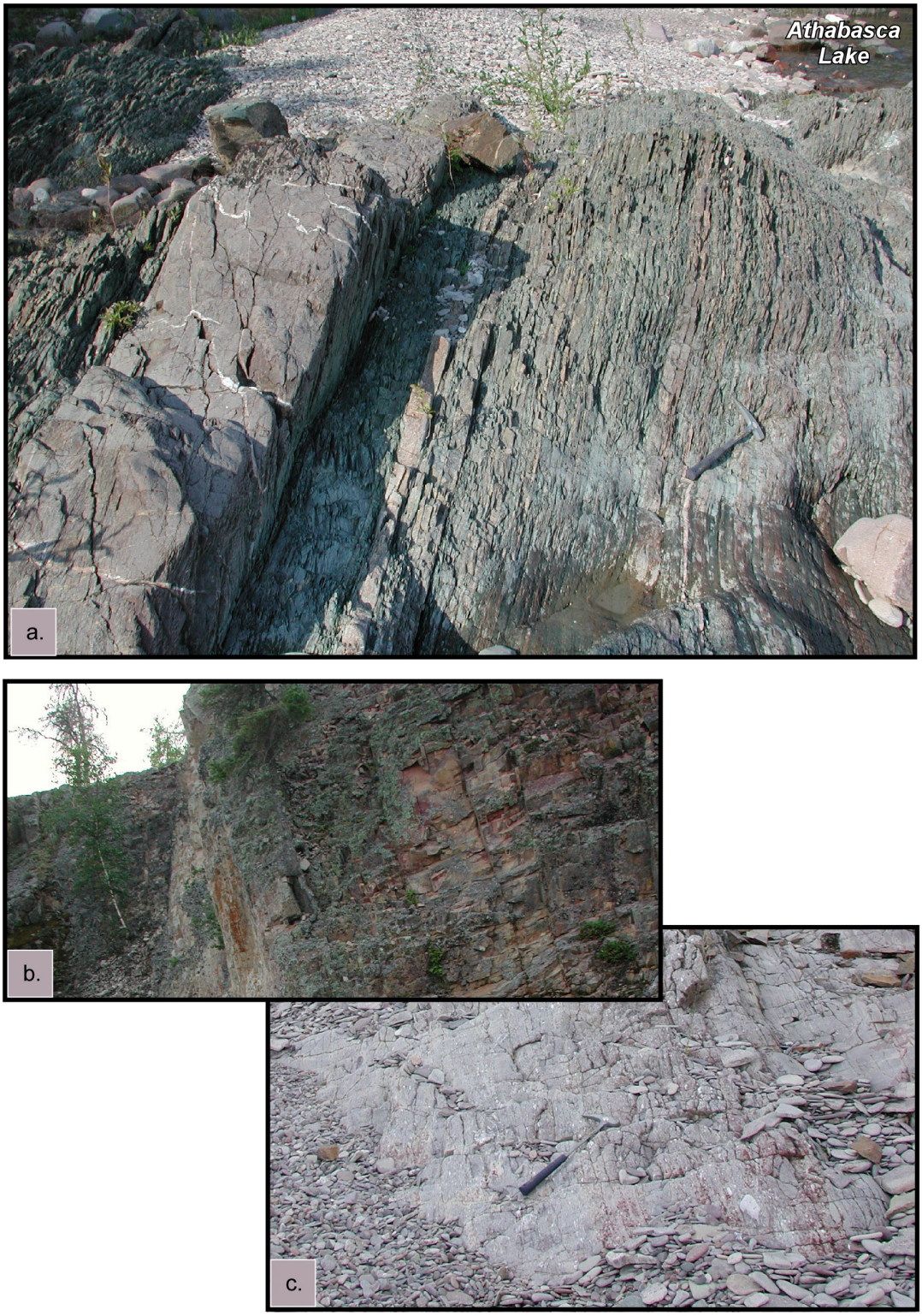


Figure 19. Burntwood lithotectonic assemblage: a) greenschist and phyllonite with hematitic quartzo-feldspathic interlayers; quartz veining in the thicker quartzo-feldspatic layers is locally much more intense than in this photo (view to northwest); b) sheared microgranite/aplite or meta-arkose layers (view to west-southwest); c) hematitic-limonitic cataclasite or metaconglomerate; subvertical foliation slightly dipping to northwest (view to west-southwest).

6 Existing Genetic Models for the Athabasca Unconformity-Associated Uranium Deposits

Genetic models for unconformity-associated uranium deposits try to account for the combined efficiency of source, transport and deposition of uranium (e.g., Cuney et al., 2003). Geological and mineralogical variations in Athabasca unconformity-associated uranium deposits may require multiple models, or variants, of a main model (e.g., Tremblay, 1982; Ruzicka, 1996; Cuney et al., 2003; Quirt, 2003). Existing genetic models for the Athabasca type uranium deposits are briefly reviewed below.

A magmatic-hydrothermal origin was briefly considered for the uraninite-bearing pegmatites in the Beaverlodge area (e.g., Robinson, 1955; Beck, 1969), but soon abandoned as the only economical concentrations were found in veins unrelated to pegmatites or any other proximal magmatism coeval with uranium deposition. Metamorphic-hydrothermal processes were proposed for the Hudsonian genesis and Grenvillian remobilization of the Beaverlodge uranium deposits by Sassano et al. (1972), Morton (1974). The lack of any significant syn or post-Athabasca tectonometamorphic event lead to dismissal of both endogen origin hypothesis and encouraged the development of models invoking supergene origin mineralizing fluids. Thus, Knipping (1974), Langford (1974, 1978) and Dahlkamp (1978) proposed pre-Athabasca Group weathering of basement rocks, transport by surface and groundwaters, and deposition in basement hostrocks under reducing conditions before the Athabasca Group had covered them. It is now clear that uranium deposits in the Athabasca Basin were formed after at least the lower Athabasca Group was deposited, as uranium and alteration minerals are found throughout the local stratigraphic column. Langford (1977) extrapolated the 'roll-front uranium' model developed for the Wyoming uranium occurrences in sandstone, to propose that Athabasca-type deposits formed through groundwater migration with uranium leaching from sandstone. However, the geometry of the role-front uranium deposits bear no resemblance with the Athabasca unconformity-associated uranium deposits, and the grades of roll-front deposits is one to two orders of magnitude lower. As a result, the concept of a significant source of uranium in basin-filling strata evolved into the "diagenetic-hydrothermal" hypothesis of Hoeve and Sibbald (1978), which with variations, became widely accepted (Hoeve et al., 1980; Kotzer and Kyser, 1995; Fayek and Kyser, 1997) and recently adopted by Jefferson et al. (2007). In its current version, this genetic model invokes diagenetic-hydrothermal processes and ore formation focused by mobile reductants released along reactivated, pre-Athabasca Group structures. While basement rocks are generally accepted as the primary source of uranium, in particular radiogenic S-type granites and pegmatites (e.g., Annesley et al., 1997, Madore et al., 2000; Cuney et al., 2003; Freiberger and Cuney, 2003; Hecht and Cuney, 2003), the mechanisms of extraction, transport and concentration of uranium remain contentious issues. For many workers, basin-infilling sediment constituted the main reservoir of uranium (e.g., Hoeve and Sibbald, 1978; Macdonald, 1980; Ruzicka, 1996; Jefferson et al., 2007). In contrast, others propose that uranium was extracted and concentrated directly from local basement rocks through shearing and hydrothermal alteration (Gatzweiler et al., 1979; Wallis et al., 1985; Annesley et al., 1997; Hecht and Cuney, 2003; Madore et al., 2000).

The idea of direct derivation of uranium from basement rocks has been recently developed into a new tectogenetic model for the Athabasca-type uranium deposits (Pană, 2006; 2007; Pană and Creaser, 2006). According to this model, the development of Athabasca unconformity-type uranium deposits is controlled by long-lived basement shear zones. The re-examination of regional tectonics and petrology of basement rocks in the region indicates that overprinting belts of high- to low-grade metamorphic tectonites record the passage of transcurrent megashears through the middle and upper crust during late Paleoproterozoic syntectonic exhumation. Uranium-enriched mid-crustal levels of the megashears were overprinted by highly porous greenschist-grade mylonite belts, which hosted active thermal-convection cells. The deposition of the Athabasca Group and the subsequent build-up of a low-permeability carapace of

hydrothermally altered clastic strata, led to the development, in places, of "pressure cooker" hydrothermal systems that maximized fluid/rock interaction for effective metal leaching at depth in the basement fault zone and ore precipitation near the Athabasca unconformity (Pană, 2007).

7 Conclusions

A brief program of float plane-supported fieldwork in August 2004 confirmed the location of the Athabasca unconformity along the northern shore of Lake Athabasca. Scintillometer traverses could not confirm previously reported individual radioactive boulders and radioactive boulder fields. Uranium metallogenetic indicators extracted from industry assessment reports (location of boulder fields and individual boulders, drillhole locations), as well as mineral occurrences (including many uraniferous sites) identified north of Lake Athabasca by the provincial and federal geological surveys, have been compiled by the AGS in GIS format. Shapefiles including these data sets accompany this report.

The exploration strategy for Athabasca unconformity-associated uranium deposits is based on empirical criteria derived from observations at regional and local scales and their coherent interpretation. Our previous observations on core from the Maybelle River uranium prospect corroborated with literature review indicates that vein-type Athabasca deposits have similar characteristics to the classic Great Bear and Beaverlodge vein uranium deposits. The latter may represent the exhumed roots of similar metallogenetic systems once capped by the Hornby Bay-Dismal Lakes and Martin groups, respectively. Thus, shear/fault zone-controlled convection through a fertile granitoid basement is considered integral to the genesis of unconformity-associated uranium deposits in the Athabasca Basin. Late Paleoproterozoic anatectic granitoid plutons and pegmatites are rich in U-Th, hosted by minerals such as monazite, zircon, titanite, and uraninite. The development of thermal convection cells in subvertical fault zone aquifers involved the upflow or lateral-flow of uranium-enriched mineralizing fluids along these permeable structures where, in places, they released uranium and other metals typically found in the unconformity-type deposits. High-grade/large-tonnage uranium deposits are likely to be found only within or very proximal to the existing or former margins of the Athabasca Basin, where the Proterozoic strata have provided an efficient seal to the basement hydrodynamic cells.

The following metallogenetic indicators are considered critical to exploration for Athabasca unconformity-associated uranium deposits:

- Ancient graphite-bearing greenschist and subgreenschist facies fault/shear zones that could have provided high porosity and occasionally high permeability for hydrodynamic cells in the fertile granitoid basement; the graphitic layers with low shear strength would favour brittle faulting and a reducing geochemical environment.
- Fault-controlled hydrothermal cells commonly develop at dilational stopovers (jogs) and bends along faults and have a cyclical activity; multiple generations of quartz and/or carbonate veining within brittle and brittle-ductile mylonites are the most favourable exploration sites for uranium and other metals.
- Proterozoic clastic strata capping such fault/shear zones triggered overpressuring of the fault-controlled hydrothermal system and led to the development of fluid-driven faulting/mineral precipitation cycles; also, clastic strata are good collectors for uranium-bearing fluids migrating up the steep high-permeability channels within the fault/shear zone. If such a collecting cap is not present, graphitic fault/shear zones can still host uranium ore, if the erosion did not proceed too deep into the ancient hydrothermal system.

- If the sedimentary cap is still present, mineral zonation (kaolinite-illite-dravite) in alteration halos vector toward the centre of an ore-forming hydrothermal plume. If the regolith is still present, red-green, deep-penetrating alteration pockets overprinting strained basement rocks may be good pathfinders for zones of enhanced permeability.

Therefore, the highest potential for new discoveries of unconformity-type uranium deposits lies in the under-explored areas overlain by the Athabasca Group. In general, intensive exploration has been carried out only in the easternmost part of the Athabasca Basin. However, the entire basal unconformity surface should be considered prospective, especially where belts of graphite-bearing greenschist mylonites and cataclasites exist.

8 Recommendations

Shear/fault zones have had the greatest control on uranium deposition in and around the Athabasca Basin. Thus, to assess undiscovered resource potential of the Athabasca Basin, *reconnaissance exploration* programs should focus on exploration methods to search for favourable structures, and ongoing exploration would benefit from integration of:

- airborne electromagnetic surveys, to identify the location, depth and characteristics of basement conductors that correlate with graphitic shear zones and ore-related alteration features;
- high-resolution airborne magnetic surveys for better interpretations of basement geology and, in particular, identification of ductile shear zones and brittle faults;
- airborne multiparameter radioactivity surveys to map the distribution of U, Th and K and their associated daughter products;
- seismic reflection surveys to provide a continuous shallow to deep structural framework of a region, including imaging of laterally continuous stratigraphic and structural features and an estimate of the location and irregularities in the unconformity; and
- airborne gravity surveys to better understand the geological framework on both regional and district scales.

Identification of basement features and other exploration vectors help focus *detailed exploration* programs using conventional exploration tools, including:

- ground radiometric, magnetic, electromagnetic, gravity surveys;
- magnetotelluric methods, which have the ability to detect both deep conductors and alteration zones;
- measuring and contouring radon or other daughter-product gas emissions as an expression of radioactive decay related to underlying uranium ore deposits;
- lake water and sediment geochemistry;
- groundwater and biogeochemical surveys;
- surficial geochemical surveys (Quaternary till) and boulder prospecting may locate in-situ to slightly transported uranium anomalies, pathfinder element anomalies and/or alteration mineralogy anomalies related to uranium alteration halos (potassic clay alteration minerals (illite), boron alteration minerals (dravite), quartz cement and quartz dissolution).

At *mine scale*, exploration and development can be guided based on structural analysis of the shear zone, associated faults, geometry of individual ore lenses and pods that could provide insights into fluid flow and ore locations and predict the overall geometry of the deposit.

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Appendix 1 – Summary of Uranium Exploration Reported in the Reviewed Assessment Reports

Table A1. Summary of uranium exploration objectives and work performed within Mineral Permits 189 and 190 (from Lehnert-Thiel, 1975), AGS ID 19750007.

Type of Work and Equipment Used	Work Accomplished	Recommendations for Further Exploration*
1- Airborne fixed-wing spectrometer and magnetometer grid survey. 2 – Helicopter-borne spectrometer rim survey. 3 - Helicopter mapping and a few landings for exact delineation of the surficial trace of the unconformity. 4 - Ground prospecting for boulders and mineralized outcrops down glacial strike of the unconformity. 5 - Geochemical muskeg sampling. 6 - Grid cutting, ground magnetometer and horizontal loop electromagnetic survey. 7 - Alpha cup radon survey <u>Equipment</u> - Twin Otter, Single Otter, Beaver and Cessna 185 - Cessna 337 fixed wing aircraft equipped with a Scintrex GAM-2"spectrometer, - Bell G 47 helicopter with a Scintrex GAM-2 spectrometer 4 - SPP2N Scintillometers (SRAT) - TV 5 Spectrometer (McPhar) - ETR-I Emanometer (Scintrex) - Alpha Radon Detector (Alpha Nuclear) - Alpha Cups (Alpha Nuclear)	Geological reconnaissance indicated some 70 miles of a partially exposed Athabasca unconformity ***- Two zones of spotty uranium mineralization*** were found near the Athabasca unconformity at: <u>Falling Sand Point</u>: a mineralized zone originally covered by 30 cm of sand was detected by hand held scintillometers; an area of 3x4 m was dug out, exposing the unconformity, with Athabasca conglomerate overlying the regolith; spotty mineralization was found within the regolith (0.024% U_30_8), but none in the overlying conglomerate. <u>Greywillow Point</u>: a mineralized zone is located 1 km north of Greywillow Point within an area of scattered outcrop, measuring 100 x 50 metres. Spotty mineralization was found in several locations within basal sandstone (0.62% U_30_8), which rests unconformably on the exposed regolith. Uranium is preferably situated where the purple colour of the basal sandstone strata changes into buff or white. These basal strata consist of conglomerate-free reworked regolithic material approx. 2 m thick. Note the complete absence of a basal conglomerate. ***- More than 400 uranium boulders*** were found between Cypress Point, Alberta, and Goose Bay, Saskatchewan: _ <u>In the Belinda - Sebastian Lake Area</u>-11 uraniferous boulders- glacial float derived from the area between Cypress Point and Greywillow Point, a distance of 15 - 20 miles ENE. Between Cypress Point and Greywillow Point, more than 350 uraniferous boulders, believed to originate within Alberta, were found within the limits of the Athabasca Basin: <u>near Falling Sand Point</u> > 200 remarkably slabby uraniferous Athabasca Sandstone boulders were found within one area measuring 50 x 50 m. The average U_30_8 content of 11 boulders is 0.51%. <u>Along the stretch of 10 km</u> of shoreline and raised beaches between Cypress Point and Greywillow Point approx. 150 uranium boulders were found as clusters and trains. <u>Fishcamp Bay Area</u>: One uraniferous sandstone boulder was found in the very southwestern portion of the area of investigation on the shoreline of Lake Athabasca near Shelter Point, Alberta. This boulder, which differs in appearance from the other sandstone boulders found some 30 miles to the N.E. The source of this boulder may be beneath Lake Athabasca. <u>Goose Bay Area</u>: 26 uraniferous boulders were found in the Goose Bay area and north of it close to the Alberta - Saskatchewan border. Only 3 days of prospecting were performed in this area, therefore, many more boulders are expected to be found. All the boulders in this area seem to originate within Saskatchewan. - Anomalous geochemical values up to 150 ppm U_30_8 were returned as a result of lake sediment sampling. The nature and the distribution of the uraniferous boulders suggest 1. several individual sources with overlapping boulder fans can be expected within both Alberta and Saskatchewan. Some of the sources however are definitely submerged beneath Lake Athabasca; 2. the presence of vein-type (Rabbit Lake-type) uranium deposits; 3. the presence of intraformational uranium deposits within the Athabasca formation of the type found at Steward Island, Lake Athabasca, and at Fond du Lac (Amok Ltd.); and 4. the presence of uranium deposits which are in close relationship to the Martin Formation unconformity, similar to occurrences in the Beaverlodge area.	1 - Establish a grid covering the area from Falling Sand Point to Maurice Bay. 2 - Carry out a ground magnetometer survey along the grid lines. 3 - Carry out a sledge-mounted spectrometer survey along the present and past (raised) beaches of Lake Athabasca. 4 - Diamond drilling in the Falling Sand Point area to locate the source of the large uraniferous boulder field. 5 - Prospecting, geochemistry and geological investigation during the summer. The uranium potential of the northwest rim of the Athabasca Basin is classified as excellent. The high cobalt content (up to 0.4% Co) of some of the sandstone samples suggests potential for other minerals which are associated with the uranium mineralization * Original recommendations from the assessment report

Table A2. Summary of uranium exploration work performed within Mineral Permits 189 and 190 (from Lehnert-Thiel and Kretschmar, 1976); AGS ID 19760006.

Type of Work and Equipment Used	Work Accomplished	Recommendations for Further Exploration*
1-diamond drilling 2-airborne electromagnetic and magnetic survey with NS and EW flight lines spaced at 0.5 km 3-ground electromagnetic and magnetic survey on a grid 4-ground prospecting 5-trenching 6-helicopter supported geological mapping 7-geochemical surveys (i.e., water sampling) 8-surficial geology studies 9-linecutting <u>Equipment</u> - Fixed-wing aircraft equipped with a Scintrex GAM-2"spectrometer, - Bell G 47 helicopter 12 - SPP2N Scintillometers (SRAT) 1- TV 5 Spectrometer 1- transit 6- magnetometers 1- downhole logging equipment Canoes, boat, motorboats	- 24 diamond drillholes totaling approx. 830 m were drilled in a grid pattern on 200 m centres in the Falling Sand Point area; the first 9 holes were drilled with AQ equipment and only 4 of these holes were logged. -no uranium mineralization was found; -overburden was up to 13 m thick; -the thickness of the Athabasca sandstone increases to the east; -the base of the Athabasca Group is a conglomeratic unit -regolith is locally interbedded with kaolinized and chloritized basement; -hydrothermally altered and fractured sandstone was found over altered basement; - Boulders found in the Falling Sand Point area have an average grade of 0.52 U_3O_8 and some show high cobalt content. L. Bayrock postulated two sources for these boulders. Exploration work has been carried out along the northwest shore line of Lake Athabasca over all land dispositions held at the time by Uranerz Exploration and Mining Ltd. in Alberta and Saskatchewan; the following work may not be pertinent to Permits 189 and 190 as it was reported for the entire area: - 92 lake and muskeg water samples and 7 lake bottom sediment samples - 73 samples of uranium mineralized outcrops and boulders; several uranium mineralized outcrops; the Fair Creek site may be of economic importance - up to September 1976, approx. 1500 uranium mineralized boulders and 6 uranium mineralized outcrops were found in the area of investigation.	Linecutting Ground magnetometer survey followed by electromagnetic survey over magnetic anomalies and faults Drilling recommended for the winter season; Additional prospecting, geological and geochemical surveys and trenching for the summer campaign of 1977 The authors considered "the uranium potential of the NW rim of the Athabasca Basin…excellent." * Original recommendations from the assessment report

Table A3. Summary of uranium exploration objectives and work performed within Mineral Permits 189 and 190 (from Lehnert-Thiel et al., 1978a); AGS ID 19780001.

Type of Work and Equipment Used	Work Accomplished	Recommendations for Further Exploration
1 - ground prospecting for uraniferous boulders 2 - magnetometer survey 3- lake water sampling <u>Equipment</u> - magnetometers (Geometrics G-816 and Geometrics G-826) - scintillometers (SRAT SPP2N) - helicopter mounted Ekman dredge	Prospecting for vein-type uranium deposits between Falling Sand Point and the Alberta-Saskatchewan border. - line cutting: 174 km within Permit 189 and 92 km within Permit 190; - ground magnetics: 118.5 km within Permit 189 and 62.8 km within Permit 190; - scintillometer prospecting: 42 traverses in Permit 189 located 15 uraniferous sandstone boulders ranging from 300 cps to 3700 cps; 30 traverses in Permit 190 located 9 uraniferous sandstone boulders ranging from 150 to 2500 cps; - geochemical surveys: 21 water and 15 sediment samples collected from Permit 189; 3 water samples collected from Permit 190. - magnetic contours map with uraniferous boulder location - location maps for lake bottom sediments samples - location map for lake water samples	No recommendations included in this report; drilling at Falling Sand Point was planned for 1978.

Table A4. Summary of uranium exploration objectives and work performed within Mineral Permits 189 and 190 (from Lehnert-Thiel et al., 1978b); AGS ID 19780003.

Type of Work and Equipment Used	Work Accomplished	Recommendations for Further Exploration*
1 – drilling 2 – detailed ground magnetometer survey Equipment - magnetometers (Geometrics G-816 and Geometrics G-826)	Following the discovery of the Maurice Bay uraniferous zone in May 1977, Uranerz continued drilling in the Falling Sand Point - Grey Willow Point area of Alberta. 106 diamond drillholes totalling more than 4100 m -Athabasca sandstone thickness varies from 0 to approx. 36 m -slightly anomalous radioactivity in sandstone within the first 2-3 m above the unconformity may reach 90-125 cps; -chloritic and hematitic alteration of basement reaches depths of almost 70 m; -basement consists of biotite-rich granite gneiss.	New geophysical techniques to better delineate boulder fans. The authors strongly recommend conversion of existing permits into leases. * Original recommendations from the assessment report

Table A5. Summary of uranium exploration objectives and work performed within Mineral Permit 244 (from Kilby and Walker, 1979), AGS ID 19790009.

Type of Work and Equipment Used	Work Accomplished	Recommendations for Further Exploration
1 - Airborne Gamma Spectrometry 2 - Ground magnetics 3 - VLF EM 4 - Horizontal Loop EM 5 - Induced polarization-resistivity 6 - prospecting and geological work Equipment - proton magnetometer Geometrics Model G-816 - Crone Radem VLF EM instrument - Apex MaxMin II EM unit - Crone "Newmont Designed" IP-IV pulse type receiver and a Scintrex IPC-8 250W transmitter - Hughes 500D helicopter Transportation by float and ski equipped aircraft helicopter, boats and snowmobiles	- a total of 232 line kilometres were flown on east-west flight lines approximately 200 m apart; profiles of uranium, thorium, potassium and total count were produced; - magnetic readings at 25 m intervals on lines approximately 200 m apart along 31.5 km of grid; one strong EW trending S dipping anomaly correlates with a stream channel; three anomalies also correspond to stream channels; - VLF EM and Horizontal Loop EM surveys were done over 32 km of the grid lines - resistivity readings were taken at 50 m and 100 m intervals on lines approximately 200 m apart along 11.5 km of grid Anomalously high uranium counts were found in: 1) a strongly hematitic quartz-pebble conglomerate with a quartz rich matrix; 2) a pink weathering medium-grained quartzite with minor secondary uranium minerals from the Athabasca Group; 3) a pink weathering, garnet-bearing gneiss boulder yielded 1400 cps	None included in this report

Table A6. Summary of uranium exploration objectives and work performed within Mineral Permits 125, 126 and 137 (from Netolitsky, 1970); AGS ID 19700011.

Type of Work and Equipment Used	Work Accomplished	Recommendations for Further Exploration*
1 - shoreline geology traverses 2 - ground radiometric examinations Equipment - SRAT SPP2-NF scintillometers - float-equipped Otter aircraft - semi-freighter canoe with motor	Fidler Point: - Eastern portion shows extensive areas of high radiometric background and associated secondary uranium stain. However, significant 'spot highs', or zones of significantly higher radioactivity are lacking. Small areas of pegmatite often gave good 'spot highs', with the best reading recorded being in the range of 4500 cps. One ground anomaly of significant intensity may be related to a northwest trending lineament and may warrant further investigation (refer to description of R.N. traverse, August 8, in radioactivity log). Belinda Lake The best radiometric readings were obtained from a 15x15x30 cm hematitequartzite boulder found on a sand plain to the southeast of Belinda Lake. Radioactivity was off-scale (>15000cps). Chemical assay of the boulder indicated 0.43 % U_30_8 and no $Th0_2$ The textural and compositional appearance of the boulder is compatible with an Athabasca Group source. The only other radioactive occurrences of significance observed in the area are located southwest of Belinda Lake (Traverse R.N., August 15), where two quartz veins, apparently gradational to pegmatites, and one strongly radioactive pegmatite occur in close proximity. The best reading obtained in the pegmatite was in the order of 6000 cps. Florence Lake Trace amounts of finely disseminated pyrite localized by very weakly developed shear zones were observed in two localities at the western end of Florence Lake. - Florence Lake area had promise of hosting vein-type mineralization (Beaverlodge type). Spot highs of 200 to 300 cps in a local background of 100 to 150 cps were found to occur in pegmatite veins and coarse grained phases of granite gneiss. Block Lake Five airborne radiometric anomalies are located in the 'mafic schist' belt (spot highs were found associated with lenses and inclusions of either granite gneiss or pegmatite but extended into the mafic rich phases); three in the mafic biotite-hornblende schist on the southwest side of the lake, and two in the mafic schist-migmatite on the northeast side of the lake. One airborne anomaly is located in the porphyroblastic biotite gneiss, east of the mafic schist belt. One anomalous zone approx. 270 m north of the NE side of the lake over an area of 7x7 m on clay and gravel overburden warrants further work (radioactivity recorded in a small 0.6 m deep test pit was in the order of 325 to 350 cps). The overburden consisted of 15 cm of 'A' zone soils and organic matter, 10 to 15 cm of sand and gravel, and an indeterminate thickness of semi-consolidated clay. Overburden thickness in the vicinity of the anomaly is estimated to be between five and twenty feet. Trace amounts (<0.5%) of pyrite in leucocratic phases of migmatite are present in nearly every outcrop at the west end of Block Lake.	1 - three areas warrant further consideration: (a) Southwest of Belinda Lake (Permit No. 125). The presence of interesting radioactivity in association with quartz veins and pegmatites requires further examination; the location of the radioactive quartzite boulder (southeast of the lake) should be examined in detail to assess whether the source of the boulder is local. (b) North of Block Lake (Permit No. 137). Anomalous radioactivity recorded in overburden is interesting because it is higher than that of the surrounding outcrops and increases with depth. The source of the radioactivity should be ascertained. (c) North of Big Bay (Fidler Point area, Permit No. 125). In this case, radioactivity may be associated with a lineament. The valley floor should be prospected in detail (possibly complemented by radon sampling) to check for anomalous zones. 2 - Re-examination of the airborne data and a subsequent plot of all values above two standard deviations is suggested for those anomalies which occur isolated from high background areas. 3 - Selected samples from the eastern portion of Permit No. 125 should be assayed for Nb, Ta, and REE. * Original recommendations from assessment report

Table A7. Summary of uranium exploration work performed at Fidler Point (from Dick, 1999); AGS ID 19770015.

Type of Work and Equipment Used	Work Accomplished	Recommendations for further exploration*
1 – radiometric surveying 2 – geological mapping and sampling <u>Equipment</u> - scintillometer Scintrex BCS-1	- Compilation of prior exploration results: - another sandstone occurrence to the north along Fidler Fault (Netolitsky, 1970); - a zone of hematite altered porphyry granite; - pitchblende in granite was reported from 1952 drilling on Fishing Creek (Griffith et al., 1962, cf. Dick, 1998); - sample pits in a pegmatite on the E edge of the property returned an average grade of 0.10% U_3O_8 (Dick, 1999); - Scintillometer traverses indicated that pegmatitic granites are consistently radiometric (1000 to 1500 cps) up to 15000cps; granite regolith values vary from 600 to 800 cps with spots up to 4000 cps; sandstone vary from 150 to 450 cps with spots up to 5000 cps - Reconnaissance geological mapping and spot mapping identified: a) at least two altered granite zones; b) faulted Athabasca unconformity along the NNW trending Fidler Fault: and c) a NE trending fault zone marked by chloritic fault gouge and regolith-like fault rocks with up to 5000 cps and an anomalous gold value of 70 ppb; - 34 geochemical samples along a 3 km stretch of the Fidler Fault - 3 samples for gold assay	- Further prospecting (mainly in the valley where a "high grade" boulder had been reported by a prospector) and geological mapping should expand outside the current property - Diamond drilling of the sandstone graben * Original recommendations from the assessment report

Table A8. Summary of uranium exploration work performed within Mineral Permits 193 and 194 (from Lehnert-Thiel and Kretschmar, 1976); AGS ID 19760006.

Type of Work and Equipment Used	Work Accomplished	Recommendations for Further Exploration*
1- diamond drilling 2- airborne electromagnetic and magnetic survey with NS and EW flight lines spaced at 0.5 km 3- ground electromagnetic and magnetic survey on a grid 4- ground prospecting 5- trenching and linecutting 6- helicopter supported geological mapping 7- geochemical surveys (i.e., water sampling) 8- surficial geology studies <u>Equipment</u> - 12 - SPP2N Scintillometers (SRAT) and 1- TV 5 Spectrometer, 1- transit, 6- magnetometers 1- down hole logging equipment - Fixed-wing aircraft & Bell G 47 helicopter - canoes, boat, motorboats	Permit 193: - two uraniferous boulders with readings of 800 cps and 5000 cps were found - one sandstone outcrop of possibly Martin Formation was found. Permit 194: - 29 ground prospecting traverses were completed - one uraniferous boulder of 3500 cps was found	• Linecutting • Ground geophysics • Drilling recommended for the winter season • Additional prospecting, geological and geochemical surveys for the summer campaign of 1977 * Original recommendations from the assessment report

Table A9. Summary of uranium exploration objectives and work performed within Mineral Permits 193 and 194 (from MacMachon, 1977); AGS ID 19770006.

Type of Work and Equipment Used	Work Accomplished	Recommendations for Further Exploration*
1 – scintillometer prospecting 2 – helicopter-supported geological mapping and pit digging 3 – limited lake geochemical surveys <u>Equipment</u> - scintillometers - helicopter	- 29 prospecting traverses and 13 geological traverses were run (to a total of 57 prospecting traverses in 1976 and 1977). - 6 anomalously radioactive boulders were located bringing the total for the area to 8; glacial striations suggest a source under Lake Athabasca. - Small patches of yellow uranium oxides (?) were observed on one traverse in cataclastic to mylonitic megacrystic granitoids. - 4 pits were dug on the beach ~2 km south of Sand Point, but the basement was not reached. - some helicopter reconnaissance mapping. - resampling of selected lakes for water and sediments. - high scintillometer readings, up to 7500 cps, found on a fracture zone overprinting a biotite-garnet gneiss unit. - possible regolith outcrop (highly silicified, slightly hematized, quartz veins) was noted near the lake shore just south of Sand Point; and approximately 5 km north of Permit 193.	• No further geological mapping. • Drilling along the Lake Athabasca shore near or at Sand Point. • Shallow trenching at the uraniferous fracture. * Original recommendations from the assessment report.

Table A10. Summary of uranium exploration objectives and work performed within Mineral Permits 193 and 194 (from Lehnert-Thiel et al., 1978); AGS Report ID 19780004.

Type of Work and Equipment Used	Work Accomplished	Recommendations for Further Exploration*
1- geochemical survey samples collected by helicopter using an Ekman dredge. 2 – pit digging (4 pits) 3 – geological mapping <u>Equipment Used</u> - 11 scintillometers - 1 Ekman standard lake sediment sampler - fixed-wing aircraft - G-4A helicopter	Permit 193: - 36 water and 36 sediment samples; no anomalous values. - 3 uraniferous Athabasca sandstone boulders (1000-12000 cps) on ancient raised beaches of Lake Athabasca. Permit 194: 18 water and 18 sediment samples; one sediment sample 4 km north of Shelter Point yielded an anomalous uranium concentration of 148 ppm, likely related to north trending fault.; - 3 uraniferous Athabasca sandstone boulders (800 to 3900 cps) along the shore of Lake Athabasca.	None included in this report. Comments on economic prospect: “the mechanism necessary for the formation of uranium deposits are operative in the area. If sandstone sub-crops are located, they would be excellent exploration targets.” * Original recommendations from the assessment report.