New Investigations of Basement to the Western Athabasca Basin

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Abstract

In 2002, investigations of basement to the western Athabasca Basin included reconnaissance outcrop mapping in the Careen Lake area of the Lloyd and Virgin River domains, the Clearwater Domain along the Clearwater River, and the Pine Channel/Fond-du-Lac areas of the Tantato Domain. In addition, diamond drill core was examined from the Dufferin, Carswell, and Hocking lakes areas. The Lloyd Domain contains granulite facies rocks including an old supracrustal package, the Careen Lake Group, that was intruded by ultramafic rocks and a poly-deformed quartz diorite suite. The Virgin River Domain contains dominantly high-grade felsic gneiss and a sliver of middle amphibolite facies supracrustal rocks, the Virgin Schist Group. Younger, less-deformed mafic dykes and granitoid rocks intrude the gneisses, including the equigranular and K-feldspar-phyric Clearwater granites of the Clearwater Domain.

The Lloyd Domain contains an old flat-lying S_1 foliation which is folded about nearly upright northeast-trending F_2 folds. The D_3 age Virgin River Shear Zone was subjected to multiple episodes of displacement. An old east-verging reverse shear zone was overprinted by at least two episodes of dextral shearing. West-northwest- to northwest-trending F_4 folds probably formed under the same stress regime responsible for late sinistral brittle-ductile displacement along the Virgin River Shear Zone. Evidence for reverse, post-Athabasca Group faulting was observed in drill core at Dufferin Lake. Most rocks in the Lloyd Domain have been subjected to two phases of high-grade metamorphism: the first reaching granulite facies as indicated by orthopyroxene-bearing diatexites and the second at least upper amphibolite facies.

The Tantato Domain is divided into upper and lower structural decks. The upper deck is dominated by high-grade supracrustal rocks and the lower deck by mylonitic rocks of plutonic origin. Most of the rocks were strongly sheared during D_2 deformation which transposed a pre-existing S_0/S_1 composite foliation. The D_2 mylonites were folded about northeast-trending F_3 axial planes and again, about east-northeast trending F_4 axial planes. Brittle reactivation of the ductile zone was episodic. Two phases of granulite facies metamorphism affected the Tantato Domain, but it is unclear which event was responsible for the unusually high pressures of at least 10 kbars and rarely >15 kbars.

The Clearwater Magnetic High, which overprints magnetic trends of the Lloyd Domain is presumed to be underlain by the Clearwater granites, although the granites are apparently magnetite poor. Magnetite crystallised during interaction of different granite phases in the batholith-scale intrusion and is commonly found along contacts and at the contacts of xenoliths of older gneiss. The Virgin Schist Group is a tectonically bound sliver of anomalously low-grade supracrustal rocks that was either down-dropped during early, east-verging thrusting or deposited subsequent to reverse shear but prior to later dextral shear along the Virgin River Shear Zone. Supracrustal rocks of the Tantato Domain are likely equivalent to the Careen Lake Group of the Lloyd Domain, however, the rocks that underlie the main magnetic highs in the two domains are dissimilar.

Keywords*: Rae Province, sub-Athabasca, Lloyd Domain, Virgin River Domain, Clearwater Domain, Tantato Domain, Virgin River Shear Zone, Virgin Schist Group, Careen Lake Group, Clearwater Magnetic High, multiply deformed.*

1. Introduction

The first full field season for the EXTECH IV "basement to the western Athabasca Basin" sub-project commenced in 2002. The purpose of this work is to better understand: 1) rocks of the newly designated Lloyd Lake Domain, formed by combining what were previously referred to as the Western Granulite and Firebag domains, 2) the relationship of these rocks with those apparently along strike in the Tantato Domain, and 3) the Clearwater Domain. The summer's activities included reconnaissance mapping at Careen Lake and in the Pine Channel/Fond-du-Lac region as well as visits to the core repositories at Dufferin Lake, Cluff Lake, and Hocking Lake (Figure 1).

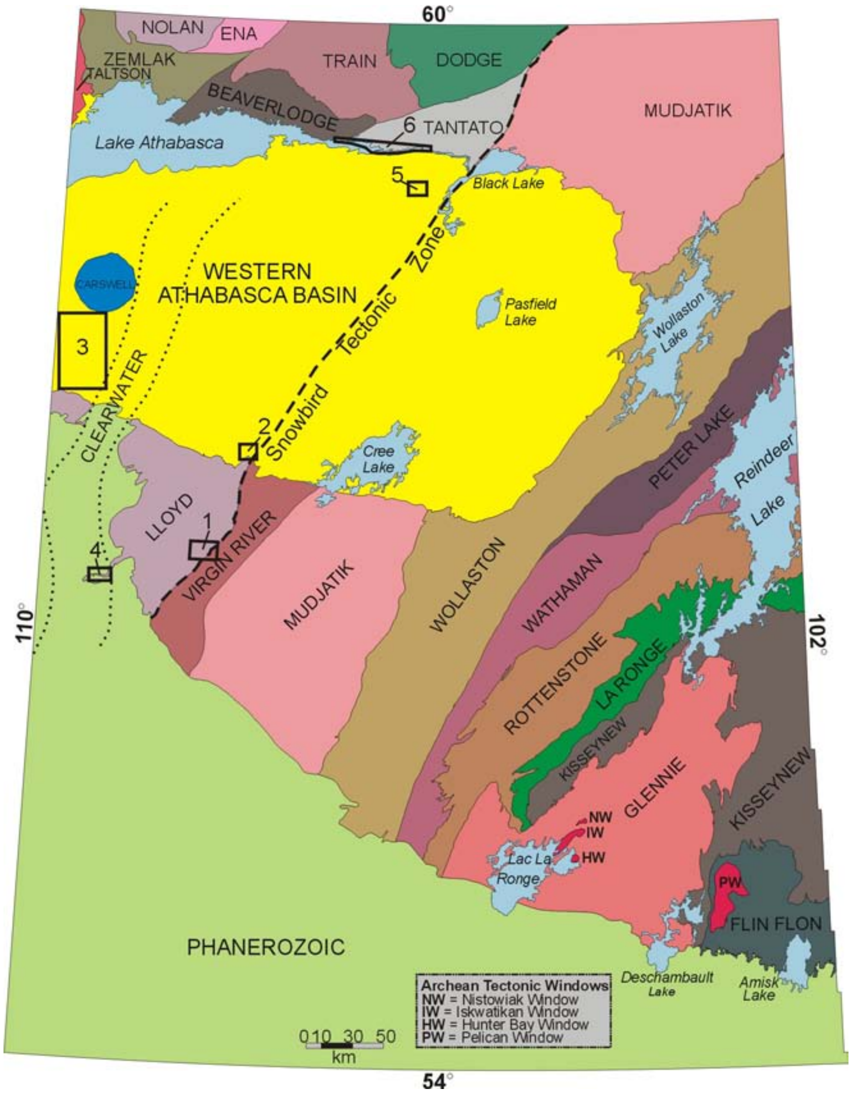

Figure 1 - Domainal map of the Saskatchewan Precambrian Shield showing areas investigated for this report (note: Clearwater Domain exposed only in the vicinity of area 4). 1, Careen Lake; 2, Dufferin Lake; 3, Carswell area; 4, Clearwater River; 5, Hocking Lake; and 6, Pine Channel/Fond-du-Lac area.

2. General Geology

Rocks that form the basement to the western Athabasca Basin (Figure 1) lie within the southern part of the Archean Rae Province. The Rae Province is the northwestern part of the Archean core to the Churchill Structural Province (Stockwell, 1961), and is separated from the Hearne Province, farther to the southeast, by the enigmatic Snowbird Tectonic Zone (Hoffman, 1988). To the west, it is bounded by the Taltson Orogen (Hoffman, 1988), and loses continuity in the southwest where geophysical data indicate that the Snowbird Tectonic Zone and the Taltson magmatic zone merge.

Most of the rocks investigated here lie in the Lloyd, Clearwater, and Tantato domains (Figure 1) of the Rae Province and their sub-Athabasca extensions. A more extensive overview of the rocks that underlie these can be found in Card (2001). The Lloyd Domain is an amalgamation of the former Firebag and Western Granulite domains and contains mainly high-grade orthogneiss and subordinate paragneiss. Poorly exposed granites and granitic gneisses of the Clearwater Domain (Sibbald, 1974; Figure 1) are presumed to be part of a north-trending, batholith-scale magmatic belt (Card, 2001) defined mainly by the Clearwater aeromagnetic high (Geological Survey of Canada, 1987), which superposes aeromagnetic trends in the Lloyd Domain. The Tantato Domain is unique in that it contains dominantly mylonitic high-pressure granulites including >2.6 Ga supracrustal rocks and ca. 2.6 Ga orthogneisses (Hanmer, 1997). It is unclear what relationship rocks of the Tantato Domain have with rocks in the Lloyd Domain. Previous workers concluded that rocks of the Tantato and eastern Lloyd domains were analogous, joining beneath the Athabasca Basin, and representative of an exotic uplift related to the Snowbird Tectonic Zone (e.g., Hoffman, 1990; Hanmer, 1997); however, others have suggested that they are equivalent to rocks found elsewhere in the Rae Province (Card and Ashton, 2002). The Virgin River Domain of the Hearne Province comprises mainly felsic gneisses purported to be the equivalent of Archean felsic gneisses of the Mudjatik Domain (Lewry and Sibbald, 1977). Supracrustal belts, of unknown age and provenance, include the relatively low-grade Virgin Schist Group (Lewry and Sibbald, 1977).

3. Geology: Southern Rae Province

a) Unit Descriptions: Careen Lake Area

The Careen Lake area, which encompasses the junction between the Lloyd and Virgin River domains (Figure 2), was re-investigated to provide a framework for rocks that potentially form basement to the western Athabasca Basin. The boundary between the Virgin River and Lloyd domains has historically been placed between the western

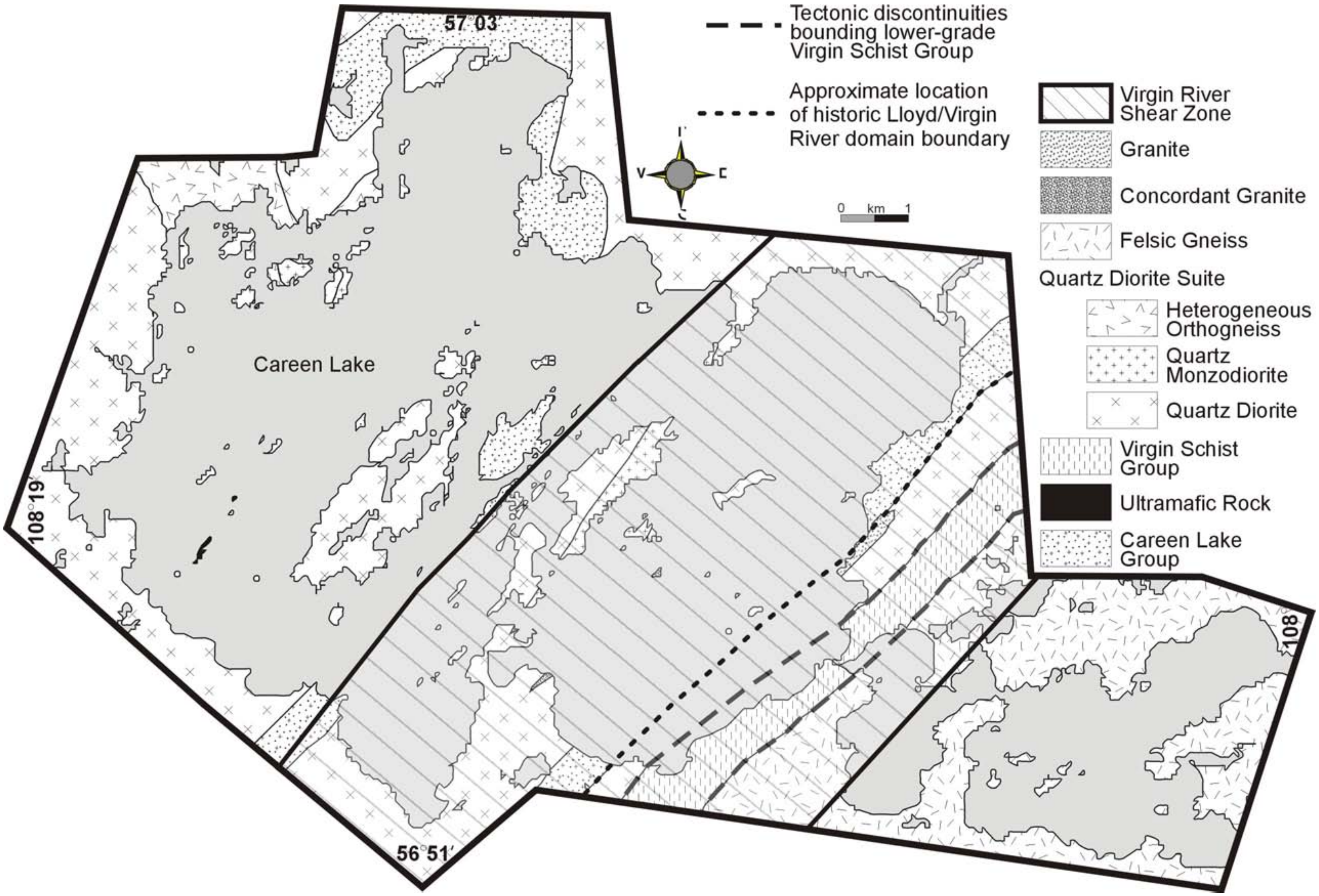

Figure 2 - Geological sketch map of the Careen Lake area. The hatched area represents the Virgin River Shear Zone. Note the dashed lines that demarcate the boundaries of the Virgin Schist Group, a sliver of lower grade rocks, and the approximate location of the historic boundary between the Virgin River and Lloyd domains.

and central gneiss belts, west of the Virgin Schist Group (e.g., Wallis, 1970), through eastern Careen Lake (Figure 2). This study suggests that although the boundary corresponds with a structural discontinuity, there is no justification for a major lithological boundary until the lower-grade Virgin Schist Group is encountered 1 km farther to the east. The high-grade gneisses on either side of the Virgin Schist Group are lithologically distinct supporting their separation, however, it is unclear whether the Virgin Schist Group is part of the Lloyd or Virgin River supracrustal belts and therefore to which domain it belongs.

Mapping was largely restricted to lakeshore exposures which were generally plentiful except where the Quaternary Cree Lake Moraine has covered them along the southern shore. Parts of Careen Lake were previously mapped by Scott (1977), Crocker (1989) and Carolan and Collerson (1989).

Lloyd Domain

"Careen Lake Group"

Scott (1985) proposed the term Careen Lake Group to describe a succession of upper amphibolite to granulite facies metasedimentary rocks in the eastern Lloyd Domain. The Careen Lake Group is mostly variably melted psammopelitic rocks and garnet diatexite, but also contains psammite, garnet-orthopyroxene diatexite, and rare boudins or blocks of quartzite, pelitic restite, amphibolite, and ultramafic rock.

Psammopelites are grey and medium grained (Figure 3) with fresh examples containing 5 to 10% biotite and 1 to 5% garnet porphyroblasts, whereas in retrogressed psammopelite, biotite has pseudomorphed garnet and on weathered surfaces has been preferentially eroded from the rock imparting a pock-marked appearance.

Garnet diatexite is white, medium to coarse grained and contains 5 to 15% biotite and 5 to 10% garnet porphyroblasts 5 to 10 mm in diameter (Figure 3). In retrogressed equivalents, garnet is partly or wholly replaced by biotite and lakeshore exposures are pockmarked creating "frothy" white rocks. Garnet diatexites are anatectic granitoid sheets also of psammopelitic origin, the difference in degree of anatexis between rocks of psammopelitic composition likely deriving from subtle variations in original composition.

Psammites are less common than psammopelite and garnet diatexite, generally constituting 10% or less of the Careen Lake Group (Figure 3). Psammites are grey, fine-to medium-grained rocks of variable composition; some varieties lack mafic minerals, whereas others contain 1 to 5% biotite, 1 to 3% garnet, and 0 to 1% sillimanite. Rarely, psammites comprise up to 1% magnetite, which is not common in other members of the group.

Quartzite was identified at only one location on Careen Lake (UTM 671785E, 6322714N, NAD 27), where it occurs as a block surrounded by the psammopelites and garnet diatexites. It is white, medium grained and contains up to 20% feldspar.

Garnet-orthopyroxene diatexite is common on the northwestern shore of Careen Lake. It differs from garnet diatexite in that it contains orthopyroxene and has a considerably higher magnetic susceptibility. It is brown to grey, medium grained and contains 5 to 15% orthopyroxene, 0 to 10% garnet, 5 to 10% biotite, and 1 to 2% magnetite. Garnet-orthopyroxene diatexite is commonly associated with garnet diatexite suggesting that it also represents an anatectic granite (charnockite) derived from sedimentary rocks.

Blocks of fine- to medium-grained ***amphibolite*** are commonly associated with the metasedimentary rocks. The origin of amphibolite is questionable. Some blocks exhibit weak layering that may represent original transposed bedding pointing to a volcanogenic origin; however, they may alternatively represent dismembered mafic dykes.

Ultramafic Rock

Ultramafic rocks are exposed on two islands in southwestern Careen Lake (Figure 2). These rocks are interpreted to be large blocks within the quartz diorite (see below). The ultramafic rocks are veined by anorthositic leucosome, giving them a schollen-like

Figure 3 - Layered metasedimentary rocks of the Careen Lake Group. Layers with reddish brown spots are garnet diatexite, blue-grey layers psammite, and the rest dominantly psammopelitic.

migmatitic appearance (Mehnert, 1968). Most are medium- to coarse-grained pyroxenites, although there are associated medium- to coarse-grained anorthosites. They are in close association with Careen Lake Group psammopelites and garnet diatexites; however, the contact between the two rock packages has been tectonically transposed. Given the grain sizes observed, an intrusive origin is preferred making these rocks younger than the Careen Lake Group.

Quartz Diorite Suite

The Careen Lake area is dominated by a quartz diorite suite. Scott (1985) interpreted these as basement to the Careen Lake Group; however, xenoliths of Careen Lake Group psammite in the quartz diorite and sheets of quartz diorite within the metasedimentary rocks indicate an intrusive relationship. The quartz diorite suite generally comprises equigranular, magnetiferous gabbroic to quartz monzonitic rocks varying in colour index from 10 to 50. The suite contains three mappable units, quartz diorite, quartz monzodiorite, and a migmatitic member, referred to as heterogeneous orthogneiss (Figure 2), as well as minor constituents. All members contain two foliations, the intersection of which defines a well developed lineation; homogeneous examples are characterised by an extension lineation.

Quartz diorite (Figure 4) is generally grey, medium grained, and contains a combination of 30 to 40% combined hornblende and biotite. Hornblende was likely dominant originally but has been largely replaced by aggregates of biotite and hornblende due to the cumulative affects of two high-grade metamorphic events. Magnetite is ubiquitous and magnetic susceptibility serves as a useful mapping tool.

Medium-grained ***quartz monzodiorite*** contains 20 to 25% combined biotite and hornblende and 1 to 2% magnetite.

Heterogeneous ***orthogneiss*** is the name applied to highly migmatitic outcrops which have metre-scale layers ranging in composition from gabbroic to quartz monzodioritic, generally separated by sheets of granitic leucosome. This unit may represent a migmatised layered intrusive body.

Rare medium-grained ***gabbro*** comprises 50 t o 55% hornblende and minor pyroxene.

Medium-grained, light grey ***felsic members***, potentially quartz monzonitic in composition, contain about 10% biotite and hornblende.

Virgin River Domain

Virgin Schist Group

The Virgin Schist Group is at the boundary between the Lloyd and Virgin River domains within the southeastern part of the Virgin River Shear Zone (Figure 2). The dominantly metasedimentary succession, which includes psammopelite, feldspathic quartzite, pelite, amphibolite, and ultramafic rocks, is distinguished from adjacent upper amphibolite to granulite facies rocks by middle amphibolite facies assemblages. The metasedimentary rocks were melted only in highly strained psammopelites where quartz-sillimanite faserkiesel were recognised. Stringers of injected granite are ubiquitous.

Figure 4 - Moderately-strained quartz diorite. Note the fine, attenuated amphibolite dyke just above the scale card.

The Virgin Schists are dominated by fine-grained phyllitic psammopelites with alternating millimetre-scale quartzofeldspathic and micaceous bands of tectonic origin. Although they are highly deformed, transposed primary layering can be inferred (Figure 5A).

Fine- to medium-grained feldspathic grey to grey-blue quartzite and feldspathic quartzite contains transposed centimetre- to decimetre-scale layering (Figure 5B).

Rare pelitic rocks are fine to medium grained and contain 25% biotite, 5% 3 to 5 mm garnet porphyroblasts, and possible staurolite (Figure 5C).

Rusty, fine- to medium-grained, dense siliceous rocks with vague layering, contain about 30% combined biotite and cummingtonite/anthophyllite, and 3 to 5%

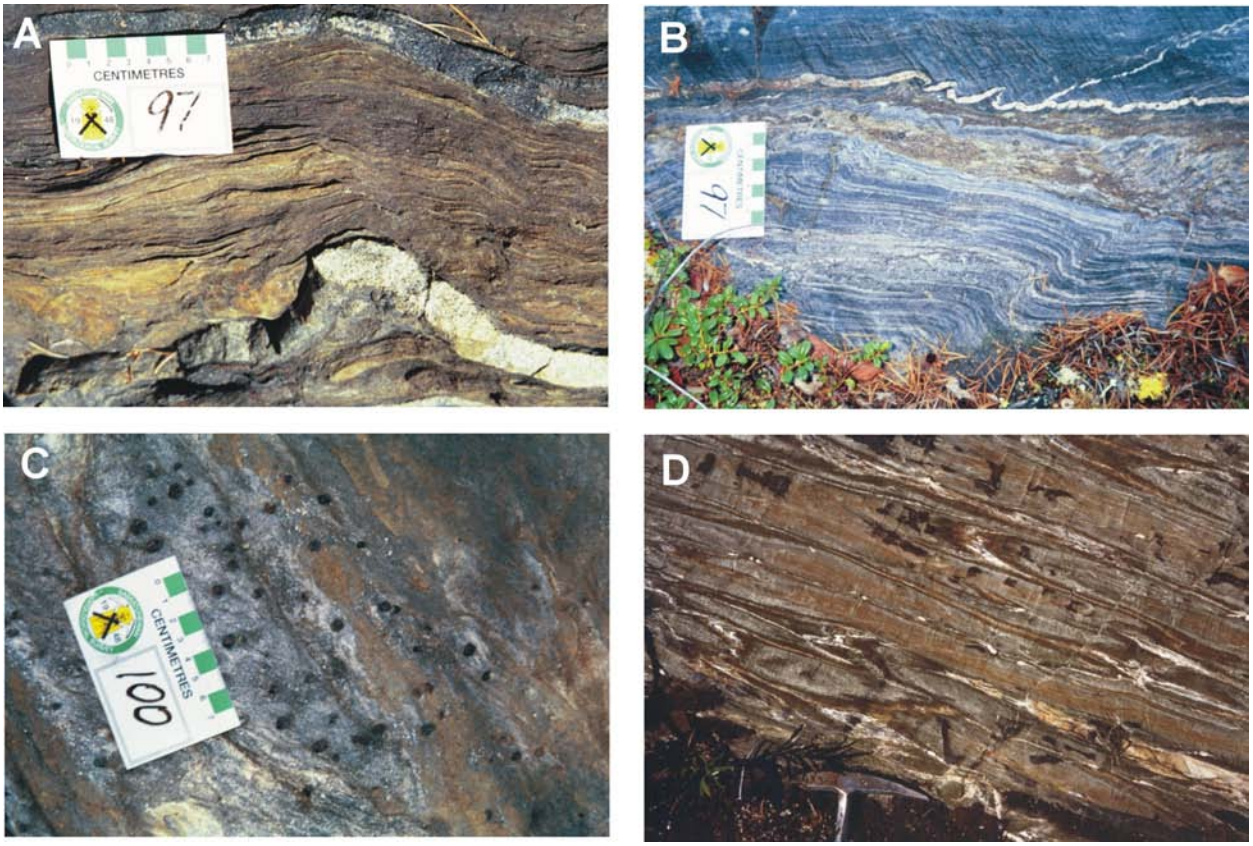

Figure 5 - A) Finely bedded psammopelites from southeastern Careen Lake (note that the quartzofeldspathic layers are resistant to weathering); B) well-layered feldspathic quartzite and psammite from southeastern Careen Lake; C) garnet porphyroblasts in muscovite-rich pelitic rocks from southeastern Careen Lake; and D) attenuated pillows in mafic volcanic rocks northeast of Careen Lake (photo provided by Charlie Harper).

sulphides. These rocks might have been derived from iron- and magnesium-rich psammopelite to pelite.

Fine-grained, amphibole-bearing mafic rocks interlayered at decimetre to metre scale with the metasedimentary rocks are interpreted as metabasalts. Although no primary volcanic features were recognised, relict pillows have been observed near Careen Lake (Harper, pers. comm., 2002; Figure 5D).

Medium-grained, black ultramafic rocks are rare.

Felsic Gneiss

Felsic gneiss, the only unit observed in the Virgin River Domain east of the Virgin Schist Group, comprises mainly various granitoid phases. The oldest is well-foliated, fine- to medium-grained poly-deformed granodioritic to tonalitic gneiss containing 5 to 10% biotite. It is unclear whether the protoliths are plutonic or sedimentary. Medium-grained amphibolite, with an unknown age relationship to the granodioritic to tonalitic rocks, is a minor component. These older components were invaded by medium-grained, foliated, centimetre- to decimetre-scale leucogranite sheets aligned parallel to the S_1 foliation. Large bodies of less-deformed, medium- to coarse-grained granite containing up to 5% biotite do not exhibit the S_1 foliation and are therefore interpreted as younger than the leucogranite. In general, the granodioritic to tonalitic rocks constitute a larger proportion of the felsic gneiss although proportions are variable.

Late Intrusive Rocks

Concordant Granite

Metre-scale sheets of medium-grained pink granite containing 1 to 3% biotite intruded the rocks described above and form small mappable bodies. They exhibit a strong S_2 foliation and have been emplaced parallel to the D_2 structural fabric, distinguishing them from younger crosscutting granite intrusions.

Mafic Dykes

Straight-sided, upper amphibolite facies mafic dykes are generally sub-parallel to, and folded by, northeast-trending F_2 folds, indicating that they are similar in relative age to the concordant granite. The salt and pepper textured amphibolites contain 50 to 55% 1 to 2 mm hornblende grains, up to 1% pyrite, commonly in veins, and up to 1% magnetite. The mafic dykes may be correlative with the Chipman dykes of the Tantato Domain, which are also spatially related to the Snowbird Tectonic Zone (Hanmer *et al*., 1994; Flowers *et al*., 2002).

Granite

Coarse-grained to pegmatitic granite dykes containing several percent tourmaline and coarse books of biotite and muscovite are ubiquitous. Although they appear internally undeformed, they were folded late during a protracted second phase of northeast-trending deformation (D_2). Metre-scale bodies of equigranular granite containing 3% biotite exhibit a very weak northeast-trending fabric and are interpreted to be the same relative age.

b) Unit Descriptions: Dufferin Lake

The Dufferin Lake uranium exploration property, near the southern margin of the Athabasca Basin, is 55 km to the northeast of, and along strike with, units at Careen Lake. Examination of drill core revealed two packages of basement rocks are juxtaposed along the Dufferin Lake fault segment of the Snowbird Tectonic Zone: deeply weathered high-grade gneisses to the west and the Virgin Schist Group to the east.

Gneisses

A deep paleoweathering profile largely precluded identification of protolith; however, these rocks are considered equivalents of the "Central Gneiss Group" of Wallis (1970). Intensely weathered, medium-grained amphibolite is represented, but medium-grained felsic gneisses with pseudomorphed garnet porphyroblasts may have sedimentary or plutonic precursors.

Virgin Schist Group

Most units are similar to exposures of the Virgin Schist Group to the south; however, other rock units, which might not have been exposed there due to weathering, were noted in core. They included pelites containing in excess of 50% graphite that are commonly tectonically brecciated and layered iron-rich psammopelites, with reddish and grey-green, millimetre-scale bands, and up to 20% hematite in some horizons. Equant and elongate pseudomorphed porphyroblasts in psammopelites might represent retrogressed garnet and andalusite, since these have been reported from exposures to the south (Wallis, 1970).

c) Unit Descriptions: Carswell Area

The basement sections of eight mineral exploration cores from the western Lloyd Domain (former Firebag Domain), in the vicinity of the Carswell Structure, were examined in core from the Erica, Beatty River, and Douglas and Shea Creek uranium exploration properties. Although these cores contain relatively thick paleoweathering profiles, fresh rock was generally encountered near the bottom of the hole.

Psammopelite

Psammopelitic rocks ranging from well-foliated and unmelted to extensively melted migmatitic gneisses are the most common metasedimentary rocks observed. Fresh examples are commonly medium grained and contain 10 to 15% biotite and 0 to 5% garnet porphyroblasts which rarely exceed 5 mm in diameter. In rare cases, psammopelites contained as much as 30 to 40% graphite and 5 to 10% sulphides. Psammopelite displays subtle compositional variation with some migmatitic varieties suggesting transposed original layering.

Quartzite

Well-foliated, medium-grained quartzite layers range from centimetre-scale to over 10 m in vertical thickness, although in some cases structural thickening due to both folding and faulting is apparent in some of the intersections. Most quartzites are classified as feldspathic or impure (c.f. Maxeiner *et al*., 1999), with impure varieties containing a few percent garnet, chlorite, diopside, or a combination of these.

Garnet Migmatite/Diatexite

This unit is characterised by its large garnet porphyroblasts in tonalitic leucosome. It is light in colour, medium to coarse grained and contains 10 to 20% partially chloritised garnet porphyroblasts up to 25 mm in diameter, 5 to 10% biotite and up to 1% graphite. These rocks probably formed by *in situ* anatexis of psammopelitic rocks considered equivalents of the Peter River Gneiss, which dominates much of the Cluff Lake area (Pagel and Svab, 1985).

Psammite

Rare fine- to medium-grained, light-grey psammite is observed as centimetre-scale layers within psammopelite or near psammopelite/quartzite contacts. It generally contains about 5% biotite or chlorite and in some cases up to 5% graphite and 3% sulphides.

Amphibolite

Amphibolite is rare, but in the Shea Creek area both weathered and fresh medium-grained, salt-and-pepper textured varieties are intercalated with the paragneiss succession. Fresh amphibolite contains 50% hornblende whereas in weathered varieties hornblende has been replaced by chlorite.

Granitic Gneiss

Light-grey to pink, granitic gneiss, found only at the base of DGS-13, is strongly foliated, medium grained and contains about 5% chloritised biotite. These rocks are similar to rocks that intrude the supracrustal package at Cluff Lake (Card, 2001).

Garnetiferous Granite Sheets

Light-grey garnetiferous granite is generally medium grained with the exception of up to 10% coarse-grained garnet porphyroblasts and occurs in foliation-parallel sheets intruding in the supracrustal rocks. It likely represents mobile partial melts from the metasedimentary succession in contrast to melts in garnet migmatite/diatexite which are considered to be derived locally.

Granite

Massive to weakly sheared, medium-grained to pegmatitic granite is ubiquitous. Fresh samples contain 3 to 5% biotite and 0 to 3% garnet porphyroblasts although in most samples the biotite has been variably replaced by chlorite and the garnet by spherical knots of chlorite.

d) Unit Descriptions: Clearwater River

Rocks of the Clearwater Domain are exposed only along a 30 km stretch of the Clearwater Gorge (Figures 1 and 6). The site was mapped by Sibbald (1974), but was revisited to investigate the origin of the strong aeromagnetic high that underlies the domain (Geological Survey of Canada, 1987).

Granitic Gneiss

The westernmost part of the gorge is dominated by granitic gneiss (Sibbald, 1974). Although this part of the domain was not visited, large xenoliths of medium-grained, well-foliated granitic gneiss containing 5 to 10% biotite were found within the Clearwater granites. Magnetite was associated with many of the xenoliths, particularly near the margins.

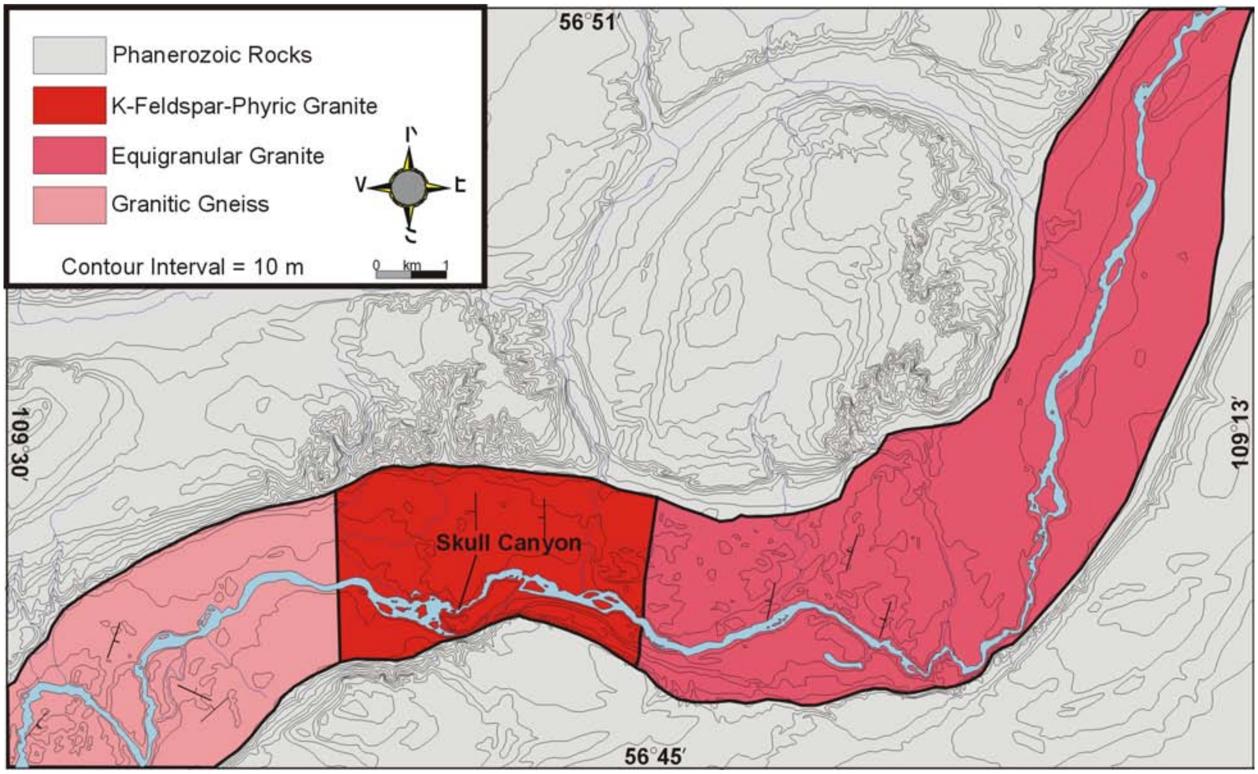

Figure 6 - Geological sketch map of the Skull Canyon region of the Clearwater River where rocks of the Clearwater Domain outcrop (based on a sketch map provided to the author by T.I.I. Sibbald who mapped the area in 1974).

K-feldspar-phyric Granite

The central part of the gorge is underlain by pink, medium- to coarse-grained K-feldspar-phyric granite ("porphyritic granite" of Sibbald, 1974) containing 5 to 10% biotite but lacking magnetite. K-feldspar phenocrysts are up to 4 cm in long dimension and commonly help to define a tectonic foliation (Figure 7).

Equigranular Granite

The eastern part of the gorge is dominated by pink equigranular granite (Sibbald, 1974) that contains about 5% biotite and is also devoid of magnetite (Figure 7). It is similar in appearance to the equigranular aplitic granite at Careen Lake.

Aplitic granites comprise very little of the total rock volume but are relatively common in the equigranular granite. They are fine-grained and contain 15 to 20% biotite and 1 to 2% magnetite (magnetic susceptibility readings >5). Relative age relationships between the two granites are ambiguous as the centimetre-scale aplitic bodies are discontinuous yet have sharp contacts with the host rock.

Figure 7 - Two phases of the Clearwater granites: equigranular granite on the left and K-feldspar-phyric granite on the right. It is unclear which phase is older and therefore these granites are thought to be broadly coeval. Magnetite is concentrated along the contact.

e) Structure

No primary features were observed near Careen Lake, although what are interpreted to be tectonically modified pillow basalts have been recognised by others in the Virgin Schist Group (e.g., Harper, pers. comm., 2002; Figure 5D). In the Lloyd Domain, a gently dipping S_1 foliation, with variable dip directions due to later reorientation, is well developed in the west in all but the late intrusive rocks, but particularly in the quartz diorite suite. In the felsic gneisses of the Virgin River Domain, S_1 dips moderately to steeply to the northwest. This is considered the equivalent of the main foliation observed in core, excluding that at Dufferin Lake. The S_1 foliation steepens towards the Virgin River Shear Zone into parallelism with northwest-dipping D_2 structures until it is no longer distinguishable. A layer-parallel schistosity formed in the Virgin Schist Group is considered correlative with S_1.

Northeast-trending F_2 folds generally have moderately to steeply northwest-dipping axial surfaces, defined by a well-developed axial planar foliation, and gently north-northwest to north-northeast plunging axes, defined by associated intersection and extension lineations. These F_2 folds typically have close to open interlimb angles and generally a low amplitude (<0.5 the wavelength) when viewed down-plunge (from the southwest) leading to gentle undulation of the S_1 foliation. A northwest-dipping axial planar S_{2a} schistosity in the Virgin Schist Group was subsequently superposed by a southeast-dipping S_{2b} crenulation cleavage with associated northeast-plunging fold axes.

Strain increases towards the Virgin River Shear Zone to a point where S_3 mylonitic fabrics replace F_2 folds as the dominant structures (Figure 2). On the basis of an internal lineation that plunges gently to the northeast, Carolan and Collerson (1989) interpreted the northwest-dipping Virgin River Shear Zone as a dextral shear zone with a minor normal component. A second, nearly down-dip lineation near the northwest boundary of the zone was not investigated thoroughly (Carolan *et al*., 1989). The Virgin River Shear Zone comprises as a composite shear zone with three parallel belts, each containing an exclusive lineation (Figure 8). The dip-slip belt, best developed in the northwest, dips moderately to the northwest and contains a nearly down-dip stretching lineation. An isolated outcrop in the Virgin River Domain to the east displays similar down-dip stretching lineations and suggests an initially wider zone of reverse shear. Limited kinematic indicators, including rotated δ-porphyroclasts and C-S fabric, indicate west-side-up, reverse displacement. The moderately to steeply dipping northwest strike-slip belt is characterised by a previously unidentified, gently southwest-plunging stretching lineation and numerous shear sense indicators including back-rotated boudins, strain insensitive fabrics, and ductile analogs of R'-shears, which consistently indicate dextral displacement with a small west-side-up component. The southeast strike-slip belt is moderately to steeply northwest dipping and exhibits a gently northeast-plunging stretching lineation. Shear sense indicators including C-S fabrics, shear bands, and δ-porphyroclasts suggest oblique dextral offset with an east-side-up component. Pegmatitic granites, which are nearly undeformed in the northwest strike-slip belt, are strongly sheared in the southeast strike-slip belt indicating that it records a younger episode of displacement. The intervening northwest and southeast strike-slip belts of the shear zone are interpreted to mark a narrow overprint of the wider dip-slip zone. The Virgin Schist Group overlaps with the southeast belt along its northwest margin where it has been subjected to dextral shearing. At Dufferin Lake, however, stretching lineations and associated kinematic

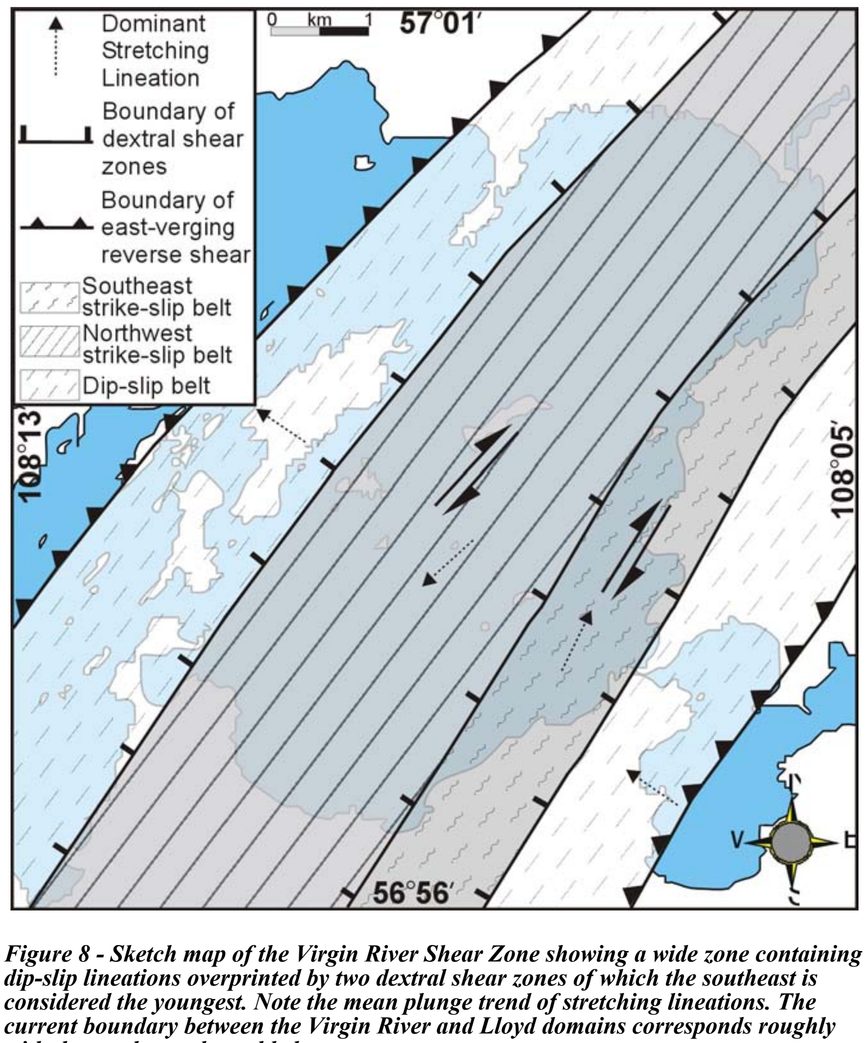

Figure 8 - Sketch map of the Virgin River Shear Zone showing a wide zone containing dip-slip lineations overprinted by two dextral shear zones of which the southeast is considered the youngest. Note the mean plunge trend of stretching lineations. The current boundary between the Virgin River and Lloyd domains corresponds roughly with the northwest dextral belt.

indicators in core indicate west-side up reverse displacement with only a minor strike-slip component, similar to the early phase of displacement.

A set of west-northwest- to northwest-trending F_4 folds recognised by Carolan and Collerson (1989) is poorly developed. These folds are consistent with formation under stress regimes as a sinistral component of the Virgin River Shear Zone and may be broadly coeval (see below).

Significant brittle deformation also affected this area as indicated by numerous lineaments that dissect the exposed Lloyd Domain. Evidence of brittle reactivation of the Virgin River Shear Zone provides an excellent example of the complex nature of this deformation. North-northeast- to north-trending, quartz-filled tension gashes at Careen Lake indicate an episode of sinistral offset along faults superposed on the high-strain ductile fabric; however, this was not the only episode of brittle offset in the zone. The Dufferin Lake fault, along which spectacular graphitic breccias (Figure 9) and extensive quartz and quartz-carbonate-hematite veining is developed, is a west-side up high-angle reverse fault which imparted nearly 200 m of vertical offset to the Athabasca unconformity based on cores examined at Dufferin Lake.

f) Metamorphism

Two phases of metamorphism are recognised in gneisses of the southern Rae Province. The first (M_1) produced garnet-sillimanite assemblages in pelitic restites and orthopyroxene-bearing diatexites which indicate medium-pressure granulite facies conditions. A second high-grade metamorphic event (M_2) reached at least upper amphibolite facies as indicated by blebby melts formed axial planar to F_2 folds and anatectic melts emplaced in the sheared off limbs of F_2 folds, parallel to their axial planes. These dykes lack the high-pressure assemblages observed in mafic dykes elsewhere along the Snowbird Tectonic Zone (see Tantato metamorphism below).

The Virgin Schist Group has not been subjected to the granulite facies conditions implied by Lloyd Domain assemblages, although it is unclear whether this is because the Virgin Schist Group is from a different level of crustal exposure or if these are younger rocks not subjected to the high-grade event. Garnet, staurolite, and possible cordierite are in pelites at Careen Lake and retrograded garnet and andalusite porphyroblasts at Dufferin Lake (see also Wallis, 1970). Staurolite+biotite+quartz and an absence of sillimanite and melt indicates temperatures of about 600ºC and andalusite indicates that pressure remained less than ~3.5 kbars during M_1. Evidence for a second phase of metamorphism includes a pervasive second fabric (S_2) and development of pressure shadows parallel to that foliation on pre-tectonic porphyroblasts. Near its northwestern boundary, where parts of the Virgin Schist Group lie within a zone of dextral shear, blebby, *in situ* sillimanite faserkiesel are aligned parallel to the S-plane of the shear zone.

4. Geology: Tantato Domain and Sub-Athabasca Extension

a) Lithology

On the basis of structural analysis, the Tantato Domain (East Athabasca mylonite triangle of Hanmer *et al*., 1994) was divided into an upper deck, an underlying lower deck, and a strain shadow (the central septum) (Figure 10) (Hanmer *et al*., 1994). The tectonic discontinuity separating the upper and lower decks also marks a sharp lithological break separating psammopelitic to pelitic diatexites and mafic to ultramafic granulites of the upper deck from mainly granitoid gneisses of the lower deck. Hanmer (1997) suggested that the Tantato Domain contained exotic rocks comprising a tectonic lozenge within the Snowbird Tectonic Zone although Card and Ashton (2002) considered the domain an uplifted zone of the Rae Province. Exposures of the upper and lower deck were examined in the Pine Channel/Fond-du-Lac region. Cores examined at Hocking Lake come from drill-holes collared near the eastern part of the break between the upper and lower decks.

Figure 9 - Fault breccia developed in graphitic pelites along the Dufferin Lake fault.

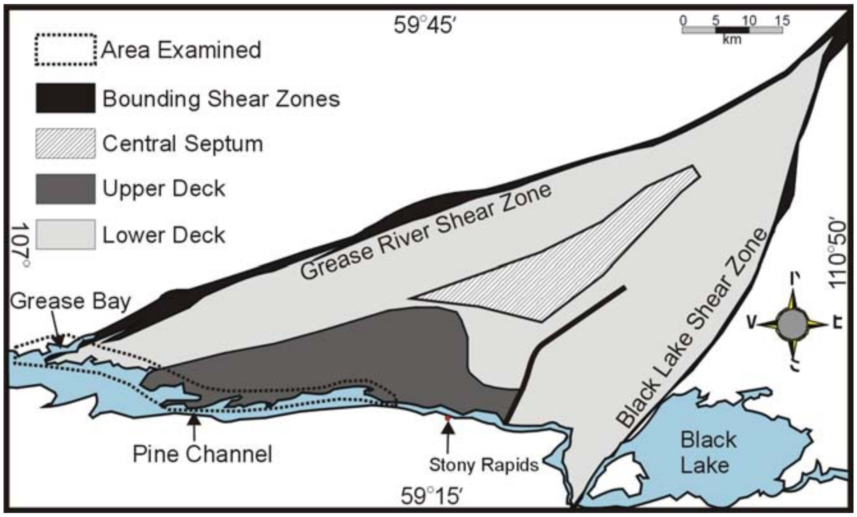

Figure 10 - Sketch map of the Tantato Domain showing the different structural compartments defined by Hanmer* et al. *(1994) and the major bounding shear zones.

Upper Deck

Garnet Diatexite

Fine- to medium-grained garnet diatexite, containing 10 to 15% garnet porphyroblasts and 5 to 10% biotite is the most common rock unit in the upper deck (Figure 11). In basement core, garnet diatexite contains clots of hematite or chlorite pseudomorphing garnet directly below the Athabasca unconformity. Generally, the diatexite has a mylonitic fabric and exhibits spectacular quartz ribboning. Garnet-rich layers, sometimes containing as much as 50 to 60% 1 to 2 mm garnet grains, within the diatexitic rocks are interpreted as restites. A pock-marked texture in lakeshore exposures resulted from weathering of retrogressed garnet porphyroblasts. Similar rocks were also observed outside the Tantato Domain in the vicinity of Grease Bay in the eastern Beaverlodge Domain.

Figure 11 - Highly strained garnet diatexite. Garnet clots are restites.

Figure 12 - Impure quartzite from the sub-Athabasca Tantato extension from the north shore of Fond-du-Lac.

Psammopelite

Psammopelite is not common but fine-grained examples with 5% biotite and 2 to 5% pinhead garnet are interlayered with garnet diatexite, suggesting they may represent unmelted sandier layers in the original sedimentary succession. Upper sections of basement core display the same hematitic and chloritic alteration as is observed in the garnet diatexite.

Layered Ferruginous Rocks

Centimetre- to metre-scale layers of ferruginous rocks, also within garnet diatexite, are internally layered at a centimetre scale and dominated by silicate minerals including garnet-grunerite-quartz. Magnetite-bearing layers are rare.

Quartzite and Psammite

Well-foliated impure quartzite containing 3% garnet is interlayered with centimetre-scale psammite and psammopelite horizons (Figure 12). Psammite is fine to medium grained with up to 5% pinhead garnet, 1% biotite, and trace graphite. Both were found only in drill core.

Mafic Granulite

Mafic granulite is most common on the north shore of Fond-du-Lac and in the central upper deck (Hanmer, 1997), but is also found as centimetre-scale layers in garnet diatexite and in drill core to the south. They are medium-grained and contain 35 to 50% pyroxene, 0 to 15% garnet, and magnetite (Figure 13). Mafic granulites display weak compositional layering that may represent transposed primary layering indicative of volcanic derivation (Slimmon and Macdonald, 1987), although an intrusive origin is not precluded.

Garnet-Orthopyroxene Diatexite

Garnet-orthopyroxene diatexite was only found associated with mafic granulites and is distinguished from garnet diatexite based on the presence of orthopyroxene and magnetite. They are medium to coarse grained and contain 5 to 10% garnet porphyroblasts up to 10 mm in diameter and 5 to 10% orthopyroxene.

Granite

Medium-grained to pegmatitic granitic rocks are omnipresent and include crosscutting dykes to strongly sheared bodies that have been largely transposed into the main regional shear fabric.

Lower Deck

Mylonitic Intermediate to Mafic Rocks

Intermediate to mafic mylonites, in the Grease River Shear Zone, contain 30% rodded plagioclase porphyroclasts 2 to 5 mm in diameter and aspect ratios of at least 5:1. The matrix is fine grained and composed mostly of hornblende and biotite which wrap around the more competent porphyroclasts. Given the diameter of the porphyroclasts, the protoliths were likely intrusive.

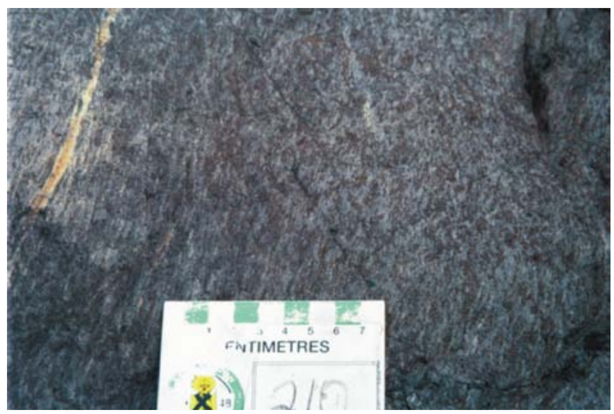

Figure 13 - Typical orthopyroxene-bearing mafic granulite.

Porphyroclastic Granodiorite

Grey granodioritic rocks exhibit a similar rodded, porphyroclastic texture to that of the mylonitic intermediate to mafic rocks. They are fine to coarse grained and contain 3 to 5% garnet and 10 to 15% biotite (Figure 14).

Figure 14 - Texture of porphyroclastic granodiorite. Note the streaked out mafic layers, which may represent either dismembered dykes or xenoliths.

Granite

White, medium-grained granites occur as centimetre-scale dykes and metre-scale bodies in the mylonitic intermediate to mafic rocks.

b) Structure

No primary features are preserved in the Tantato Domain. The regional composite $S_0/S_1/S_2$ gneissosity which includes at least two generations of leucosomal layering, is well developed in garnet diatexite. The S_0/S_1 foliation was transposed into parallelism with D_2 structures. High-temperature D_2 shearing produced north-northeast- to northeast-trending mylonites, which dip moderately to steeply to the northwest, and an associated gently to moderately southwest-plunging stretching lineation. Associated north-northeast- to northeast-trending F_3 buckle folds with axial planes that are co-planar to the mylonitic fabric, are considered exclusive from the mylonites as they are widespread outside the area of high strain (e.g., Ashton and Card, 1998). They have close interlimb angles, gently to moderately plunging axes, and an axial planar foliation defined by flattened quartz and reoriented biotite which overprinted the mylonitic fabric and produces a well-developed S_2/S_3 intersection lineation. F_4 folds strike northeast to east-northeast with steeply southeast-dipping axial planes. An axial planar S_4 foliation is defined by reoriented biotite and flattened quartz and/or garnet grains. Although rare, they resulted in Type 3 interference with F_3 folds and folding of the L_2 stretching lineation.

Brittle-ductile to brittle faults formed by reactivation of the ductile high-strain zone are beneath linear valleys and characterised by abundant hematite and locally well-developed breccias. In drill core, they are typified by spectacular breccias, graphite-rich phyllonites, pervasive fracturing, and quartz and quartz-carbonate-hematite veins.

c) Metamorphism

The Tantato Domain is unique in that it contains unusually high-pressure granulite facies rocks. Minimum P-T estimates are 800ºC and 10 kbars (Williams *et al*., 1995) with P-T conditions locally achieving 900º to 1000ºC and >15 kbars (Snoeyenbos *et al*., 1995; Baldwin *et al*., 2001), suggesting 50 km of burial depth. Age determinations indicate at least two phases of granulite-facies metamorphism: the first at ca. 2.6 Ga (Hanmer, 1997); and a second at ca. 1.9 Ga (Baldwin *et al*., 2000), although it remains unclear during which phase the high-pressure assemblages formed. Textural evidence observed this summer corroborates the evidence for two episodes of high-grade metamorphism. Two generations of leucosome are common in garnet diatexite as are two generations of garnet porphyroblasts, the latter of which overgrows the D_2 fabric. Indicators of high-pressure conditions include garnet-clinopyroxene-plagioclase assemblages in mafic granulite and garnet rims around plagioclase in granitoid rocks of the lowest structural levels in the upper deck. Late replacement of garnet porphyroblasts by biotite and chlorite is common.

5. Discussion

a) Relationship of the Careen Lake Group to Metasedimentary Rocks Observed in Core

Supracrustal units observed south and southwest of the Carswell Structure are similar in overall composition and proportion of components to metasedimentary rocks at Careen Lake. Scott (1985) grouped all the supracrustals of the Lloyd Domain with the Careen Lake Group and given that rocks of the western (former Firebag Domain) and the eastern Lloyd Domain (former Western Granulite Domain) are now considered correlative, it is likely that the supracrustal package in the west is similar if not equivalent to the Careen Lake Group.

b) Origin of the Clearwater Aeromagnetic High

The lack of magnetite in the Clearwater granites was both unexpected and puzzling. As the fabric of the Clearwater aeromagnetic high overprints magnetic trends in the surrounding Lloyd Domain (e.g., Card, 2001) and the presence of abundant granite in the only exposures of rocks underlying the magnetic high, the feature was attributed to a granitic batholith. One plausible explanation for the source of the magnetite is co-mingling magmas. Although monotonous outcrops of either K-feldspar-phyric or equigranular granite contain little magnetite, areas where the two are in contact tend to be highly magnetic (Figure 7). Furthermore, aplitic dykelets are also highly magnetic and may represent a more extensive phase of the Clearwater Granite suite. Magnetite also seems to have grown during partial digestion of xenoliths of granitic gneiss. Field observations therefore suggest that the Clearwater aeromagnetic high is underlain by a complex, multi-phase intrusion in which magnetite is localised in contacts between specific phases.

c) Origin of the Virgin River Shear Zone and Virgin Schist Group

The Virgin Schist Group has been included in the western Virgin River Domain (Lewry and Sibbald, 1977) based on a perceived similarity to high-grade supracrustal rocks to the east. The Virgin Schist Group is also similar in lithologic character to the Careen Lake Group and other supracrustal units in the Rae Province. For example, it compares to the relatively low-grade parts of the Archean Murmac Bay Group (Ashton *et al*., 2000).

The geological history of the Virgin River Shear Zone, and Virgin Schist Group, which is juxtaposed along its eastern margin, is complex. The down-dip stretching lineations characteristic of the northwest belt and in the gneisses of the western Virgin River Domain together with shear sense indicators suggest that early west-side-up reverse displacement occurred throughout the entire shear zone. Evidence for this early displacement was obliterated in the central and southeast belt by later dextral reactivation of the shear zone (Carolan *et al*., 1989). Narrow zones of brittle deformation were superimposed on these.

Weakly metamorphosed supracrustal rocks in the footwall of the Virgin River Shear Zone can be explained in several ways. The down-dip stretching lineation developed in some of the Virgin Schists suggests that they represent a tectonic slice that was down thrown from shallower crustal levels during the early east-verging thrust event. In this scenario, the dextral shear observed along the northwest margin of the Virgin Schist Group resulted from a younger dextral reactivation. Alternatively, the apparent absence of the M_1 metamorphic event, together with the restricted occurrence of the down-dip stretching lineation may indicate that the Virgin Schist Group was deposited as a result of the early west-side-up event, prior to the dextral overprint.

d) Comparison of the Tantato and Lloyd Domains

Regional aeromagnetic signatures are interpreted to indicate that rocks of the Tantato Domain extend beneath the Athabasca Basin and re-emerge in the Lloyd Domain. Given the observations presented here, it seems unlikely that magnetic highs in the two domains derive from equivalent rock units. Magnetic highs in the upper deck of the Tantato Domain are underlain by mafic granulites of probable volcanic origin whereas magnetic highs at Careen Lake are underlain by the quartz diorite suite. Although the supracrustal rocks in the upper deck of the Tantato Domain are far more voluminous than the supracrustal rocks in the Lloyd Domain, there is significant similarity between supracrustal packages in both domains, suggesting they may be correlative.

6. Conclusions

Based on the information presented above the following preliminary conclusions can be drawn:

1) There is significant similarity between the supracrustal successions in the western and eastern Lloyd Domain which in part justifies their amalgamation into a single domain.
2) The Clearwater Magnetic High is underlain by the late multi-phase Clearwater granite which contains large xenoliths of older granitic gneiss. The interaction between the different phases of the granite and between the granite and the xenoliths apparently led to crystallisation of significant magnetite, causing the anomalously high magnetic signature.
3) The Virgin River Shear Zone formed during multiple events originating with west-side-up reverse displacement. The middle amphibolite facies Virgin Schist Group was juxtaposed between granulite facies gneisses of the Lloyd Domain and felsic gneisses of the Virgin River Domain during this event and later deformed and partially melted(?) during dextral shearing. The Virgin Schist Group has lithological similarities to other supracrustal packages in the Rae Province, however, its provenance is not yet known.
4) Although there appears to be continuity in magnetic trends between rocks of the Tantato and Lloyd domains beneath the Athabasca Basin, the rocks that underlie magnetic lineaments thought to be correlative are different lithologically. That notwithstanding, there is significant similarity between the supracrustal packages preserved in the two domains and they are likely correlative.

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8. References

Ashton, K.E. and Card, C.D. (1998): Rae Northeast: A reconnaissance of the Rae Province northeast of Lake Athabasca; *in* Summary of Investigations 1998, Saskatchewan Geological Survey, Sask. Energy Mines, Misc. Rep. 98-4, p3-16.

Ashton, K.E., Kraus, J., Hartlaub, R.P., and Morelli, R. (2000): Uranium City revisited: A new look at the rocks of the Beaverlodge mining camp; *in* Summary of Investigations 2000, Volume 2, Saskatchewan Geological Survey, Sask. Energy Mines, Misc. Rep. 2000-4.2, p3-15.

Baldwin, J.A., Bowring, S.A., and Williams, M.L. (2000): U-Pb geochronological constraints on the nature and timing of high-grade metamorphism in the Striding-Athabasca mylonite zone, northern Saskatchewan, Canada; *in* GeoCanada 2000, June 2000, Calgary, Conference CD, ext. abstr. #892.

Baldwin, J.A., Williams, M.L., and Bowring, S.A. (2001): Petrology and metamorphic evolution of high-pressure granulites and eclogites from the Snowbird Tectonic Zone, northern Saskatchewan; Geol. Assoc. Can./Mineral. Assoc. Can., Jt. Annu. Meet., May 2001, St. Johns, Abstr. Vol. 26, p6-7.

Card, C.D. (2001): Basement rocks to the western Athabasca Basin in Saskatchewan; *in* Summary of Investigations 2001, Volume 2, Saskatchewan Geological Survey, Sask. Energy Mines, Misc. Rep. 2001-4-2, CD B, p321-333.

Card, C.D. and Ashton, K.E. (2002): The sub-Athabasca Basin Rae Province in Saskatchewan: Is there a lozenge separating the Rae and Hearne cratons?; Geol. Assoc. Can./Mineral. Assoc. Can., Jt. Annu. Meet., May 2000, Saskatoon, Abstr. Vol. 27, p17.

Carolan, J. and Collerson, K.D. (1989): Field relationships and kinematic indicators in the Virgin River Shear Zone; *in* Summary of Investigations 1989, Saskatchewan Geological Survey, Sask. Energy Mines, Misc. Rep. 89-4, p98-101.

Carolan, J., Crocker, C.H., and Collerson, K.D. (1989): Structural relationships of the Western Granulite Domain and the Virgin River Shear Zone; *in* Summary of Investigations 1989, Saskatchewan Geological Survey, Sask. Energy Mines, Misc. Rep. 89-4, p102-104.

Crocker, C.H. (1989): Geology of the Careen Lake west area (update) (NTS 74C-16, 74F-1); 1:20 000 prelim. map *with* Summary of Investigations, 1989, Saskatchewan Geological Survey, Sask. Energy Mines, Misc. Rep. 89-4.

Flowers, R.M., Baldwin, J.A., Bowring, S.A., and Williams, M.L. (2002): Age and significance of the Proterozoic Chipman dike swarm, Snowbird Tectonic Zone, northern Saskatchewan; Geol. Assoc. Can./Mineral. Assoc. Can., Jt. Annu. Meet., May 2002, Saskatoon, Abstr. Vol. 27, p35-36.

Geological Survey of Canada (1987): Magnetic anomaly map of Canada, 5th ed.; Geological Survey of Canada Map 1255A, 1:5 000 000 scale.

Hanmer, S. (1997): Geology of the Striding-Athabasca Mylonite Zone, Northern Saskatchewan and Southeastern District of Mackenzie, Northwest Territories; Geol. Surv. Can., Bull. 501, 92p.

Hanmer, S., Parrish, R., Williams, M., and Kopf, C. (1994): Striding-Athabasca mylonite zone: Complex Archean deep-crustal deformation in the East Athabasca mylonite triangle, northern Saskatchewan; Can. J. Earth Sci., v31, p1287-1300.

Hoffman, P.F. (1988): United plates of America, the birth of a craton: Early Proterozoic assembly and growth of Laurentia; Annu. Rev. Earth Planet. Sci., v16, p543-603.

__________ (1990): Subdivision of the Churchill Province and extent of the Trans-Hudson Orogen; *in* Lewry, J.F. and Stauffer, M.R. (eds.), The Early Proterozoic Trans-Hudson Orogen of North America, Geol. Assoc. Can., Spec. Pap. 37, p15-39.

Lewry, J.F. and Sibbald, T.I.I. (1977): Variation in lithology and tectonomorphic relationships in the Precambrian basement of northern Saskatchewan; Can. J. Earth Sci., v14, p1453-1467.

Maxeiner, R.O., Gilboy, C.F., and Yeo, G.M. (1999): Classification of metamorphosed clastic sedimentary rocks: A proposal; *in* Summary of Investigations 1999, Saskatchewan Geological Survey, Sask. Energy Mines, Misc. Rep. 99-4.1, p89-91.

Mehnert, K.R. (1968): Migmatites and the Origin of Granitic Rocks; Elsevier, Amsterdam, 405p.

Pagel, M. and Svab, M. (1985): Petrographic and geochemical variations within the Carswell Structure metamorphic core and their implications with respect to uranium mineralization; *in* Laine, R., Alonso, D., and Svab, M. (eds.), The Carswell Structure Uranium Deposits, Saskatchewan, Geol. Assoc. Can., Spec. Pap. 29, p55-70.

Scott, B.P. (1977): Reconnaissance geology: Upper Clearwater River area (part of NTS area 74F); *in* Summary of Investigations 1977 by the Saskatchewan Geological Survey, Sask. Dep. Miner. Resour., Misc. Rep., p13-16.

__________ (1985): Geology of the upper Clearwater River area; Sask. Energy Mines, Open File Rep. 85-2, 26p.

Sibbald, T.I.I. (1974): La Loche (north) area: Reconnaissance geological survey of 74-C-NW and 74-C-NE; *in* Summary Report of Field Investigations by the Saskatchewan Geological Survey, Sask. Dep. Min. Res., p38-45.

Slimmon, W.L. and Macdonald, R. (1987): Bedrock geological mapping, Pine Channel area; *in* Summary of Investigations 1987, Saskatchewan Geological Survey, Sask. Energy Mines, Misc. Rep. 87-4, p28-33.

Snoeyenbos, D.R., Williams, M.L., and Hanmer, S. (1995): Archean high-pressure metamorphism in the western Canadian Shield; European J. Mineral., v7, p1251-1272.

Stockwell, C.H. (1961): Structural provinces, orogenies, and time classification of rocks of the Canadian Precambrian Shield; *in* Lowden, J.A. (ed.), Age Determinations by the Geological Survey of Canada, Geol. Surv. Can., Pap. 61-17, p108-118.

Wallis, R.H. (1970): The Geology of the Dufferin Lake Area (west half) Saskatchewan; Sask. Dep. Miner. Resour., Rep. 132, 59p.

Williams, M.L., Hanmer, S., Kopf, C., and Darrach, M. (1995): Syntectonic generation and segregation of tonalitic melts from amphibolite dykes in the lower crust, Striding Athabasca mylonite zone, northern Saskatchewan; J. Geophys. Resear., v100 (B8), p15,717-15,734.