The Wollaston Group and Its Underlying Archean Basement in Saskatchewan: 1989 Fieldwork and Preliminary Observations

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A detailed investigation of the geological characteristics of the Wollaston Group and the underlying Archean basement with respect to uranium mineralization was initiated last year under a joint venture agreement between Saskatchewan Energy and Mines and Saskatchewan Research Council. This work was reported in the 1988 Summary of Investigations (Annesley and Madore, 1988) and elsewhere (Annesley, 1989a and 1989b; Annesley and Madore, 1989). The results and recommendations of this preliminary investigation indicated that further work was necessary. As a consequence, a new joint venture agreement between Cameco, CEGB Exploration (Canada) Ltd., Cominco Ltd., Interuranium Canada Ltd., PNC Exploration (Canada) Co. Ltd, Uranerz Exploration and Mining Ltd., Saskatchewan Energy and Mines, and Saskatchewan Research Council was negotiated. The major purpose of this project is to refine the field, petrographic, geochemical, and stratigraphic attributes of the various rock units of the Wollaston Group after "looking through" the Hudsonian structural-metamorphic overprint. A secondary aspect of the project is to determine the role of lithostratigraphy, structure, and metamorphism in the metallogenesis of unconformity-type uranium deposits. The ultimate goal is to add to or modify present metallogenic models of this deposit type, and hence improve the exploration strategy.

This report describes the progress of this summer's work. Some of the preliminary observations and interpretations, which are reported here, may change or be modified by further research. The final SRC report of this project, including the results and interpretation of all work and analyses, will be completed in April of 1991, and released after a two year period of confidentiality.

1. 1989 Field Work

The field work in 1989 was carried out by a two-person field party during the months of June, July, and August. The large study area is approximately trapezoid in shape (Figure 1). Its western boundary is defined by the Key Lake road from km 80 to kilometre 220, and the eastern boundary by a line trending northwards, parallel to and east of the Rabbit Lake road, from Kilometre 160 to Hatchet Lake. The northwestern boundary extends from Kilometre 220 of the Key Lake road northeastwards to Hatchet Lake, and the southeastern boundary from Kilometre 80 of the Key Lake road northeastwards to Kilometre 160 of the Rabbit Lake road.

Sub-areas and drill holes of importance to be mapped, core logged, and/or sampled were identified from compilation, previous studies in the region, and from recommendations of K. Kogler (Uranerz Exploration and Mining Ltd.), V. Sopuck (Cameco), H. Quarch (Interuranium Canada Ltd.), and T.I.I. Sibbald (Saskatchewan Energy and Mines). Ten different sites (see Figure 1 for location) were visited during the summer, including:

1) Kapesin Lake - Zimmer Lake (outcrop and drill core),
2) MacArthur River (drill core),
3) Key Lake road (outcrop),
4) Karin Lake (outcrop and drill core),
5) Bullseye Lake (drill core),
6) Nekweaga Bay - Morell Lake (outcrop),
7) Cigar Lake - Tibia Lake (drill core),
8) Robertson Lake (drill core),
9) Rabbit Lake - Collins Bay (drill core and outcrop) and
10) Dragon Lake - Raven Lake - Horseshoe Lake (outcrop and drill core).

Outcrops and drill core sites were visited via foot, road, air, and water. Approximately 130 outcrop samples and 460 drill core samples were collected. Thirty drill holes were core logged and sampled for construction of stratigraphic sections and another 39 drill holes were examined and sampled for purposes of stratigraphic correlation.

2. General Geology

The study area lies within the Wollaston Domain and the eastern part of the Mudjatik Domain, two of the major subdivisions of the Cree Lake Zone of the Trans-Hudson Orogen (Lewry *et al.*, 1985).

The Wollaston Domain is a northeast-trending belt, which typically comprises folded metasediments overlying antiformal Archean granitoid gneisses. The metasedimentary rocks are assigned an Aphebian age

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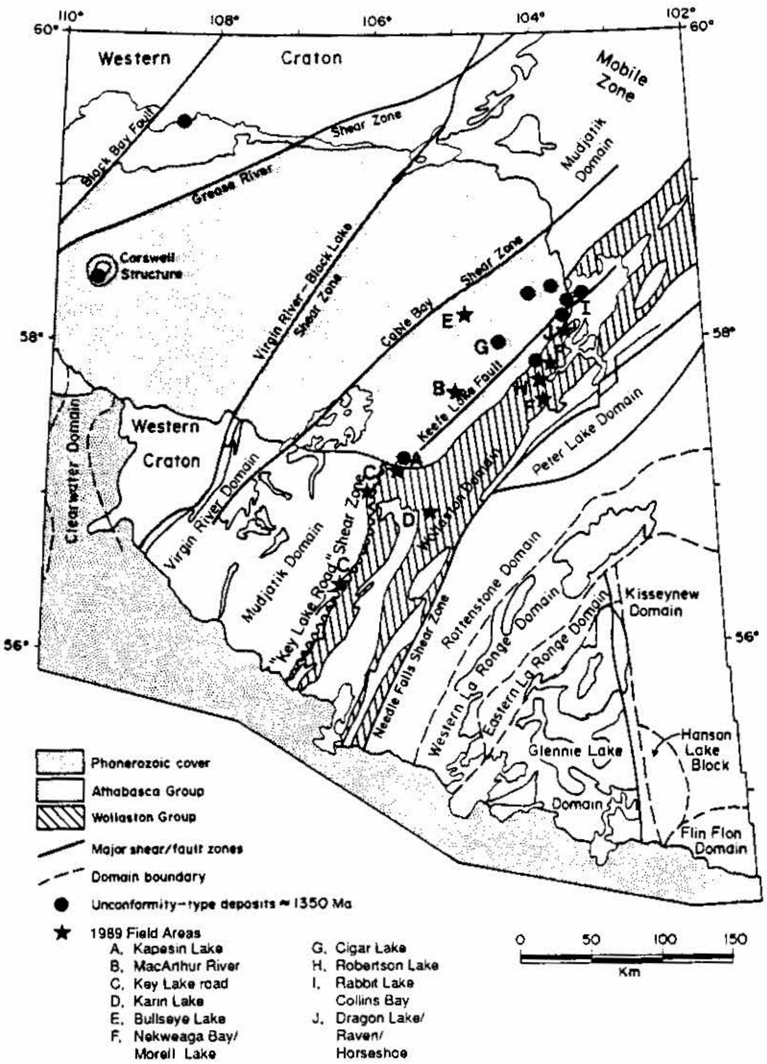

Figure 1 - Location of 1989 field work areas.

on the basis of their apparent unconformable relationship with the underlying Archean granitoid gneisses and their subsequent metamorphism during the Hudsonian Orogeny. A broadly defined stratigraphy comprising four main lithological units has been documented for the Wollaston Group (Lewry and Sibbald, 1977 and 1979; Sibbald, 1983). Metamorphic textures and mineral assemblages observed within the Wollaston Domain rocks indicate metamorphic conditions of low to medium pressure, middle amphibolite to lower granulite grade.

The rocks of the Wollaston Domain have been affected by polyphase deformation involving several events of folding, thrusting, and faulting superimposed on an early (D1) penetrative foliation. As a result, most primary features of the Wollaston Group metasediments have been obliterated. The earliest recognized folds (D2 event) are overturned to recumbent, and trend easterly. These folds and the regional gneissosity have been refolded by two nearly orthogonal sets of moderately plunging upright folds. Superimposed on these folding events are several generations of ductile to brittle thrusting and faulting, the latest of which consists of northerly-trending faults and joints.

The Mudjatik Domain is characterized by its non-linear nature, and is composed predominantly of felsic gneisses of granitic to granodioritic-tonalitic composition with subordinate components of supracrustal and late intrusive rocks. The granitoid gneisses are considered, for the most part, to be highly tectonized and reactivated plutonic bodies of Archean age (Lewry and Sibbald, 1980; among others). The characteristic dome and basin pattern of the Mudjatik Domain has been interpreted as produced from the interference of two orthogonal fold sets superimposed upon earlier formed migmatite lobes (Lewry and Sibbald, 1977, 1979, and 1980; Sibbald, 1983). Metamorphic mineral assemblages within the Mudjatik Domain indicate maximum metamorphic conditions of upper amphibolite to lower granulite grade.

a) Key Lake Road

A description of lithological units, structure, and metamorphism has been provided previously (Annesley and Madore, 1988). Part of the 1989 field work was designed to define the characteristics and extent of the boundary zone between the Mudjatik and Wollaston domains, and to determine if the boundary zone is similar to the contacts of Archean granitoid gneiss domes and overlying Aphebian rock types.

New observations in this area may be summarized as follows:

1) Some of the quartzofeldspathic gneisses of uncertain origin (Annesley and Madore, 1988), mapped previously as "meta-arkoses", display one or more of

the following characteristics: a) relict igneous textures, in most instances recrystallized and annealed, b) an overall mineral composition typical of igneous rocks, although mineralogically altered to varying degrees, and c) intrusive field relationships (e.g. intrusive contacts).

2) Fine-grained to coarse-grained granitic layers within these quartzofeldspathic gneisses, interpreted previously as anatectic sweats within meta-arkoses, can be shown to have formed by progressive deformation of an irregular network of pegmatite and aplite veins and dykes within granite-granodiorite gneiss.
3) The transition from relatively undeformed granitoids of the Archean basement complex of the Mudjatik Domain to migmatitic and mylonitic orthogneisses at the boundary of the Mudjatik and Wollaston Domains is continuous and gradational over several hundred metres.
4) Mylonitization and transposition appear to be common features at the boundary of the Mudjatik and Wollaston Domains. It is very common to observe several generations of foliations and structures like sheath and tubular folds, mineral stretching lineations, disrupted folds, and rotated porphyroclasts and porphyroblasts.
5) During peak regional metamorphism, the Archean granitoids and the overlying Wollaston Group metasediments became migmatized to varying degrees. Several generations of thin layers and lenses of leucosomes are present, and these are invariably folded, sheared, and boudinaged.

b) Karin Lake Area

Detailed mapping and sampling was carried out within the northeasterly elongated Karin Lake granite dome and the surrounding supracrustal rocks of the Wollaston Group. Particular attention was given to recently burned over outcrops, since they provide the best exposure. The major lithological units and geological relationships identified by the authors are similar, in most instances, to those reported by Thomas (1979).

Although petrographic and geochemical results are not available at this time, the following stratigraphic sequence was determined (oldest at bottom):

8) Psammitic Gneiss (Meta-Arkose) - in part psammopelitic to calcareous
7) Psammopelitic Gneiss - in part calcareous with subordinate calc-silicate gneiss
6) Garnetiferous Pelitic Gneiss aluminosilicates - in part calcareous, migmatitic, and mylonitic
5) Graphitic Pelitic Gneiss cordierite garnet sillimanite - migmatitic, in part mylonitic; contains lateral facies changes of meta-conglomerate and iron formation
4) Archean/Lower Proterozic Boundary - includes varying proportions of aplite, amphibolite, and pegmatite with subordinate components of Archean granitoids and Aphebian Wollaston Group metasediments, in part strongly migmatitic and/or agmatitic
3) Garnetiferous Granite (Archean) - fine grained to medium grained, relatively homogeneous, weakly foliated to gneissic; in part granulitic (greasy luster) and mylonitic
2) Grey "Marginal Phase" Granitoid (Archean) - fine grained to medium grained, heterogeneous, gneissic; in part migmatitic and mylonitic
1) Archean Granite - fine grained to medium grained, relatively homogeneous massive to moderately gneissic, pink to greyish pink

Other significant observations include the following:

1) Both ortho- and para-gneisses are commonly migmatitic, especially near the Archean/Proterozic boundary. Thin leucosome layers and lenses, in part boudinaged, are a common feature in both.
2) Three major phases of folding have deformed the rocks of the Wollaston Group and the underlying Archean basement: a) F2 - E-W (D2 event) b) F3 - NE-SW (D3 event) c) F4 - NW-SE (D4 event).
3) Deformation makes it difficult to determine the nature of the original Wollaston Group - Archean basement contact. However, the presence of meta-conglomeratic rocks at the eastern edge of the Karin Lake dome suggests an unconformity. In general, the apparently unconformable contact between the Wollaston Group and Archean basement has been transposed into concordance by tectonism.
4) Severe shortening characterizes both Archean basement and Wollaston Group rocks, as implied by tight folding structures.
5) The intensity of deformation increases closer to the contact between the Archean basement granitoids and the overlying Wollaston Group metasediments.
6) Conflicting senses of shear (sinistral and dextral) are shown by kinematic indicators within the Archean/Lower Proterozoic boundary zone, however this phenomenon may be consistent with folding of the boundary zone.

c) Morell Lake and Nekweaga Bay Areas

The authors carried out detailed mapping and sampling in the Morell Lake and Nekweaga Bay areas between kilometre 160 and 220 of the Rabbit Lake road. The geology of the Morell Lake and Nekweaga Bay areas was mapped at a 1:63,360 scale by Chadwick (1966, 1967). Some of the present authors' lithological identifications, stratigraphic relationships, and structural interpretations for this region differ from those of Chadwick (1966, 1967) and other previous workers.

Some preliminary observations of this area are as follows:

1) The Archean basement complex of this map area is composed of a heterogeneous assemblage of plutonic granitoid rocks. This variable suite ranges from fine-grained to coarse-grained, essentially equigranular to inequigranular-porphyritic (porphyroclastic and/or porphyroblastic), relatively massive to strongly gneissic and/or mylonitic granites, granodiorites, and tonalites.
2) All the granitoid rocks, except for pegmatite and aplite veins and dykes, have preceded or accompanied major deformation.
3) Migmatites are common locally, especially in the transitional zone between Archean granitoid gneis-

ses and overlying Wollaston Group pelitic to psammopelitic gneisses.
4) Mylonitization and boudinage also occur in the transitional zone.
5) As along the Key Lake road, some of the quartzofeldspathic gneisses mapped previously as "meta-arkoses" exhibit textural and mineralogical characteristics more typical of highly strained gneissic granitoids. In particular, this is a common feature in outcrops west of Boland Lake and northeast of Hills Lake.
6) The tectonic fabrics observed in the lithological units, especially the pelitic gneisses, suggest three folding events, among which the second appears to have been dominant. Early, E-W trending, recumbent to overturned D2 folds are deformed by two upright folding events. Superposition of these folds on the early folds gave rise to the complex, highly variable interference patterns observed in plan and section views. The ductility contrasts between rock types appears to have been an influential factor on the development of folds and hence on the interference patterns produced.

d) Raven-Horseshoe-Dragon Lakes Area

The authors undertook detailed mapping and sampling in the area extending from Raven and Horseshoe Lakes to Dragon Lake. Outcrop exposure in the area is fair to poor. The area has been previously mapped at reconnaissance and detailed scales (Wallis, 1971; Sibbald, 1979 and 1983). D. Quirt (this volume) of the Saskatchewan Research Council is presently working on the metallogenesis of the Raven and Horseshoe deposits.

A tentative stratigraphy for this area from the Archean basement upwards is as follows (oldest at bottom):

6) Meta-quartzites + sillimanite - in part conglomeratic
5) Psammitic Gneisses - in part calcareous, interlayered with or transitional into meta-quartzites
4) Psammopelitic and Calc-silicate Gneisses - in part migmatitic and mylonitic, transitional into or interlayered with pelitic and psammitic gneisses
3) Pelitic Gneisses + graphite + aluminosilicates + garnet - invariably migmatitic with variable leucosome content, in part mylonitic, locally calcareous
2) Archean/Lower Proterozoic Boundary - transitional zone of variable dimensions, comprising a chaotic mixture of pegmatite, amphibolite, aplite, and migmatite
1) Archean Granitoid Gneisses - heterogeneous, variable composition, in part migmatitic and mylonitic, massive to strongly gneissic

A summary of preliminary field results and interpretations follows:

1) The distribution of rock units, in general, is similar to that reported by Sibbald (1983).
2) The authors have recognized a mylonitic "straight" zone of quartzofeldspathic gneisses, west of Horseshoe Lake. These rocks were originally interpreted as "meta-arkoses", however, less deformed gneisses in this zone retain textural and mineralogical characteristics typical of granitoid gneisses (i.e. orthogneisses).
3) The orthogneisses within the "straight" zone are intensely deformed and strongly migmatitic. Generally, they are fine grained to coarse grained with abundant *lit-par-lit* quartz and feldspar leucosomes and cross-cutting quartz and pegmatite veins. Locally, the orthogneisses are cut by dyke- or sill-like amphibolite sheets, which have also been tectonically disrupted.
4) The contact of the orthogneisses with pelitic to psammopelitic gneisses of the Wollaston Group occurs as a transitional zone consisting of pegmatite, amphibolite, and migmatite (locally agmatitic).
5) As in other parts of the Wollaston Domain, the rocks have been strongly deformed and have been affected by three periods of folding with similar trends to those described earlier.

Note: amphibolite occurs throughout the sequence, however it is more voluminous at the Archean/Lower Proterozoic boundary.

3. Problems and Recommendations

There are many speculations regarding the geological characteristics of the Wollaston Group and the underlying Archean basement. Some of the major problems to be resolved have been reviewed recently by Annesley (1989a). Of these unresolved questions and others put forth, it is the authors' opinion that the identification of the protolith(s) of the quartzofeldspathic gneisses remains the most problematic. The problem of identifying the protolith to quartzofeldspathic gneisses is not new (see Spry, 1969, p279-284; Lewry *et al.*, this voume, for examples). This enigma, in combination with structural and metamorphic complexities, unconformities, and facies changes greatly hinder attempts in refining the lithostratigraphy of the Wollaston Group. The authors recommend, in addition to this present project, that more continuous detailed mapping and core logging, as well as geochronologic and thermobarometric studies, are needed to fully understand the stratigraphy and geological history of the Wollaston Group and its underlying Archean basement.

a) Ongoing and Future Work

Ongoing work in the fall of 1989 includes the following:

1) preparing samples for analytical work; all samples will be processed for thin sections and 250 representative samples will be submitted for major and trace element analysis, REE will be determined on selected samples; and
2) analyzing and interpreting structural data.

Future work in the winter of 1990 will concentrate on:

1) a petrographic study of all outcrop and drill core samples collected from this summer's field work;
2) a geochemical study of representative samples from this summer's field work;

3) construction and correlation of stratigraphic sections, in particular across the Archean/Aphebian boundary;
4) correlation and integration of petrographic, structural, lithostratigraphic and geochemical results with existing stratigraphic and lithogeochemical data (Annesley, 1989a and 1989b; and confidential company files) of the Wollaston Group and its underlying Archean basement; and
5) Interim Report.

Potential field areas selected for the summer of 1990 are:

1) Trout Narrows and surrounding area, Wollaston Lake
2) Highrock Lake
3) Michael Lake
4) Harrison Peninsula/Ivison Bay/Pow Bay/Ashley Peninsula
5) Selected drill hole sites.

4. Acknowledgements

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Critical review of this manuscript by T.I.I. Sibbald is greatly appreciated. Any speculative interpretation remains the sole responsibility of the authors.

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