Uranium Metallogenic Studies: III Cluff Lake

by C. T. Harper

Geological investigations of the Amok (Canada) Ltd. uranium ore bodies in the Cluff Lake area continued in 1977 with 1:50,000 scale geological mapping of the central basement core of the Carswell circular structure. During this year's program the relationship of the ore bodies to the regional geology was examined. Some of the data obtained from geochemical studies initiated in 1976 (Harper, 1976) are also reported.

In conjunction with the present project, Dr. J. Hoeve of the Saskatchewan Research Council has studied relationships between mineralization, structure, and alteration present in diamond drill core and bedrock exposure.

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General Geology

The Cluff Lake ore bodies lie at or near the southern edge of the central core of the Carswell circular structure (Fig. 1). The structure is generally considered to have resulted from meteorite impact (Robertson and Grieve, 1975). Features such as deformation lamellae in quartz (Anon., 1974, Tapaninen, 1975), shatter cones, intrusive and possibly extrusive volcanic-like breccias and/or flows, shattered cobbles and boulders in the basal conglomerates of the Athabasca Formation and the crater-like morphology, lend credibility to this origin. The Carswell structure belongs to the class of complex hypervelocity craters defined by Robertson et al. (1975, p. 2) as "generally larger than 4 km in diameter, with an uplifted central peak and a slumped or depressed rim. In the larger structures, a series of uplifts and depressions can occur concentric with the central peak resulting in a multi-ring structure. The target rocks are shocked and the bolide (meteorite) as an entity is destroyed on impact". On the other hand Currie (1967) suggested the Carswell structure to result from crypto-explosion; that is the explosive release of internal crustal pressures.

As the Carswell structure has been well described by previous workers (Currie, 1967; Anon, 1974; and Tapaninen, 1975 and 1976) only the central core will be considered in the present work. This core, approximately 19 km in diameter, is an uplifted block of Precambrian gneisses which along the outer margin is in contact

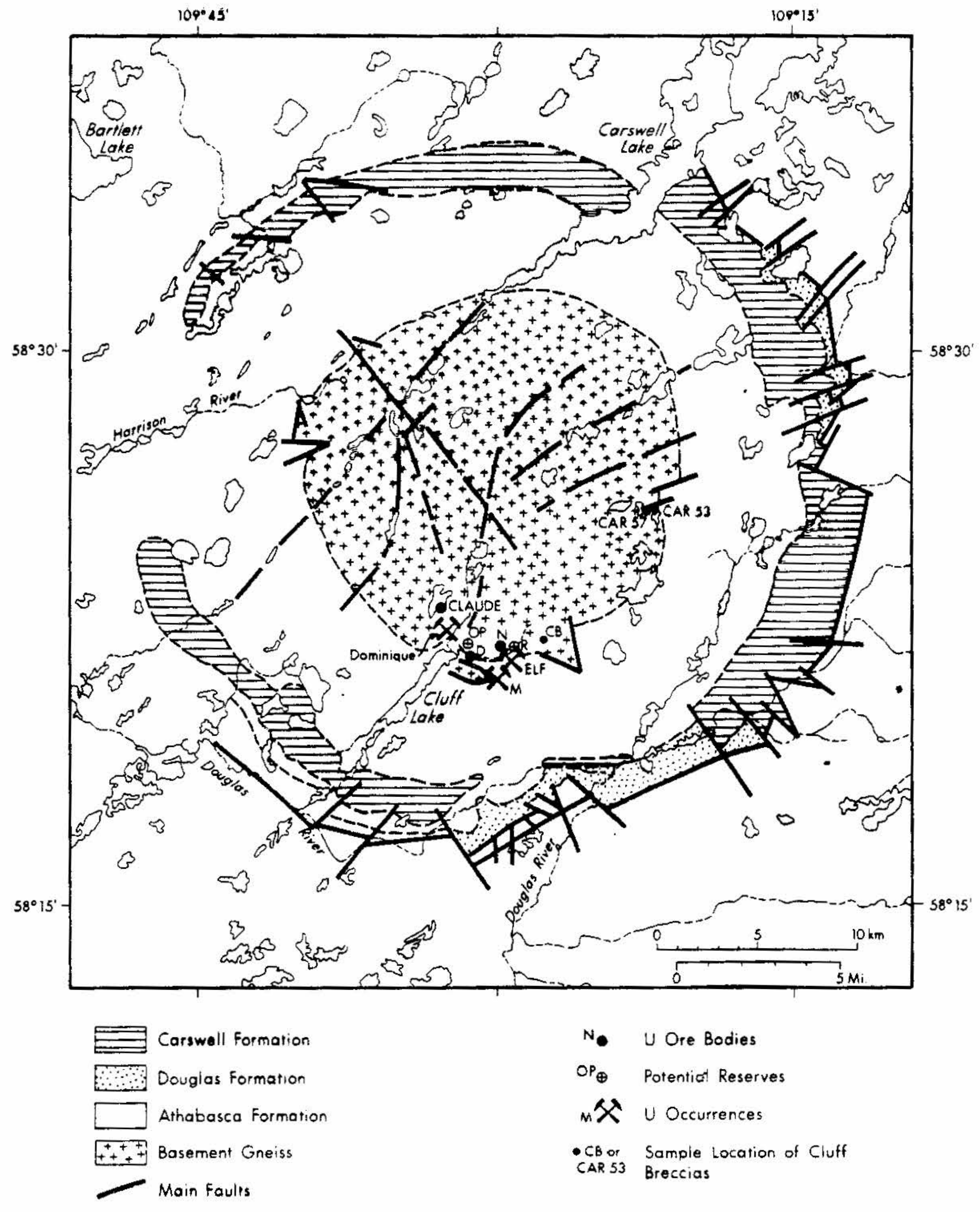

Fig. 1. Generalized geology of the Carswell Structure (modified from Anon., 1974). Also shown are the locations of various uranium deposits and occurrences as well as locations of Cluff Breccia samples mentioned in text.

with and sometimes overlies deformed sandstones and conglomerates of the younger Athabasca Formation. This contact is generally marked by a tangential or circular fault system, which is in turn truncated and offset by radial faults. The sub-Athabasca Formation unconformity is exposed in many places. Strongly altered hematitic 'regolithic' basement and sandstones, pelites, and basal conglomerates of the Athabasca Formation are exposed in both normal and inverted relationship.

Geology of the Central Core

The central core is extensively covered by muskeg and lakes, as well as by glacial and post-glacial gravels, sands and silts. Bed rock exposures comprise less than 1 percent of the area. The more resistant rock types; granitoids, pegmatoids and quartzo-feldspathic gneisses, are most commonly encountered in outcrop, whereas the other rock types are generally only found in trenches, road cuts, or diamond drill core.

The central core appears to be formed by interlayered reddish granitoid gneisses, quartzo-feldspathic and pelitic gneisses. These rocks have undergone repeated folding followed by late cataclastic deformation. Metamorphism reaching granulite facies conditions in part if not all of the area was followed by retrogression to amphibolite and possibly even greenschist conditions.

The metamorphic rocks have been subdivided by Amok geologists into the following lithologic units (Anon, 1974; Tapaninen, 1975; and Herring, 1976):

1. Pelitic Gneiss:
   (a) garnet-cordierite gneiss
   (b) garnet-sillimanite gneiss
2. Quartzofeldspathic Gneiss:
   (a) fine-grained quartz-feldspar-biotite gneiss
   (b) porphyroblastic granitoid gneiss
3. Mafic Gneiss:
   (a) pyroxene bearing granulite
   (b) amphibolite

All these units have been intruded by Cluff Breccia dykes.

In this report and on the accompanying map the following lithological units have been adopted:

1. Red Gneisses (Include 2b and 3a of Amok)
2. Quartzo-feldspathic Gneisses (Include 2a of Amok)

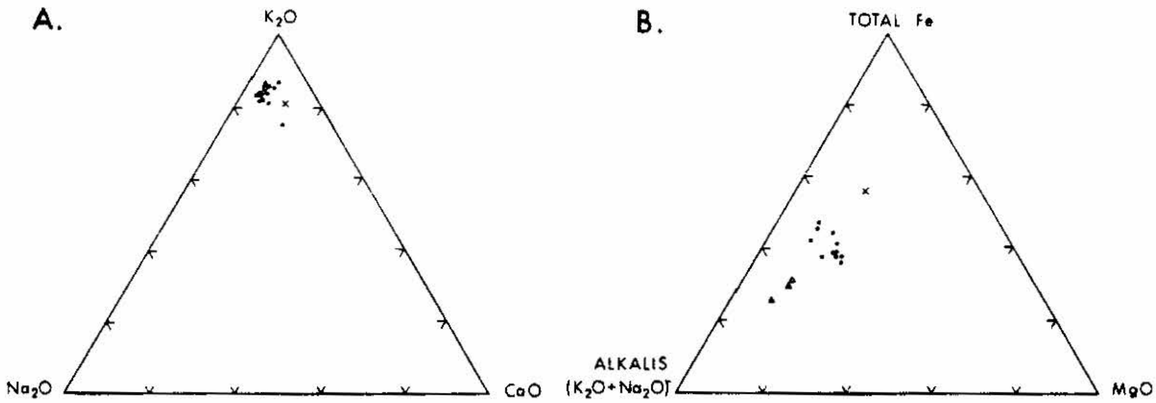

Fig. 2. Ternary diagrams for Cluff Breccias. Symbols designate sample locations; (o) Car 53, (x) Car 57, and ( ) northeast of ELF radioactive zone.

Table 1. Summary of Whole Rock Analyses of Cluff Breccias

	CAR 53 Average 7616-H044-H054*	CAR 57 7616-H055	NE ELF Zone 7717-211E, F, & G**
SiO_2	61.84	70.4	68.57
Al_2O_3	15.24	13.3	14.33
FeO	-	-	2.51
Fe_2O_3	8.66	5.5	1.46
MgO	3.06	1.7	1.33
CaO	0.47	0.35	0.30
K_2O	6.87	2.7	6.9
TiO_2	0.61	0.50	-
P_2O_5	0.04	0.15	-
MnO	0.05	0.06	0.03
Na_2O	1.03	0.30	0.97
H_2O+	2.83	3.54	-
H_2O-	0.84	1.08	-
H_2O	-	-	3.63
CO_2	-	-	0.04
Total	101.54	99.58	100.07

*Samples 7616-H044 to H055 analysed by U. of Regina; total iron given as Fe_2O_3

** Samples 7717-211E, F. & G analysed by Bondar-Clegg & Co. Ltd.

3. Pelitic Gneisses (Include 1a and 1b of Amok)
4. Lean Iron-Formation
5. Mafic Gneisses
6. Pegmatoids Rocks
10. Cluff Breccia

The red gneisses (Unit 1) are generally pinkish-grey to red, medium grained, equigranular granoblastic to pegmatitic textured, weakly to strongly foliated, and contain remnants of more mafic metasediments or metavolcanics. In places a well developed 1-10 cm scale layering consisting of alternating felsic and mafic layers indicates a strong metamorphic differentiation. Quartz is commonly grey to blue.

The quartzo-feldspathic gneisses (Unit 2) form an interlayered complex in which quartz and feldspar are generally abundant. The rocks are typically light to dark grey, fine to medium grained, equigranular, and poorly foliated. Layering is generally well developed. Limonitic staining on fracture and cleavage surfaces is common, but iron sulphides are not obvious. Garnets, 1 to 2 mm in diameter, are present in small amounts in many outcrops and many show partial to nearly complete chloritization. Bluish quartz is ubiquitous in these gneisses in the eastern part of the area, whereas it is rare in the west.

The pelitic gneisses (Unit 3) are most abundant in the western part of the area. Based on his examination of drill core, Herring (1976) reports that only garnet-sillimanite pelites occur in the extreme east whereas only garnet-cordierite pelitic gneisses occur in the west. This distinction was not noted in the field.

Two isolated occurences of lean iron formation (Unit 4) were located, one east of Bridle Lake and the other east-northeast of Lac Louise. The latter occurrence is the largest outcropping over an area approximately 60 m x 240 m. Magnetite ranges from about 5 percent to as much as 30 percent of the rock.

The mafic gneisses (Unit 5) are a minor rock type commonly occurring as thin bands or lenses up to 2 m thick within Units 1, 2, and 3. They are typically dark green to black and poorly foliated, despite a high content of chlorite. Several bodies of mappable dimension were located, two of a metagabbro or metabasalt and another of pyroxenite. One of these metagabbros occurs with the iron formation at Bridle Lake. The other is located south-southeast of Lac Louise and like the Bridle Lake occurrence appears to be massive unfoliated, hornblendic gabbro. These rocks are dark grey to black, coarse grained (3-5 mm) and contain minor disseminations of iron sulphides. The pyroxenite is exposed in a large trench and is detected in drill chips in an area south-southwest of Lac Claude. The rock, which is green, Structure

Three episodes of deformation are recognized which on the basis of a single K-Ar date of 1973 m.y. (Herring, 1976), are believed to be of Hudsonian age.

The earliest phase produced the regional foliation, presumably axial planar to first generation folds although no folds of this period have been recognized. The second phase deformed the regional foliation into tight overturned folds but did not produce a new well defined foliation. These structures are dominant in the area and probably control the distribution of rock units. The third phase structures refold the first two producing low amplitude warps and open folds in a general northerly direction, on both a minor (outcrop) and major regional scale. It is believed that cataclastic deformation may have accompanied the third deformation, with tectonic breccias and mylonites forming along the major fold axial surfaces. These zones could provide suitable sites for uranium mineralization.

The regional trend of the foliation has a sweeping S shape from the northwest to the southeast. There is apparent dislocation along two major lineaments, the Carswell-Bridle Lakes lineament and the Cluff Lake lineament, which form part of the radial fault system of the Carswell structure. It is possible that these lineaments represent reactivated mylonitic shear zones of the Hudsonian orogenic period.

Metamorphism and Alteration

The metamorphism and alteration of the basement rocks has been studied in detail by Herring (1976). A summary of his findings indicate the following sequence of events:

1. Prograde regional metamorphism to the granulite facies during the major deformation phase.
2. Retrogressive metamorphism to the upper amphibolite facies probably related to hydration accompanying emplacement of pegmatoids.
3. Retrogression (not defined) associated with mylonitization.
4. Alteration due to weathering of the basement during the pre-Athabasca erosion period.
5. Pale green to white chloritic and argillic alteration of the rocks above and below the sub-Athabasca unconformity by low temperature (200-250°C) hydrothermal activity with associated uranium mineralization.
6. Alteration (chloritic and argillic)associated with the formation of the Carswell structure.

Superimposed are shock metamorphic effects.

Herring implies that the chloritic and/or micaceous alteration is associated with the period of hydrothermal activity accompanying uranium mineralization. However, there are two distinct types of chloritic alteration, one dark green or black and the other pale green. There is also some evidence to indicate that these two types of chlorite are of different ages. The dark chlorite is generally widespread, occurring on fracture, joint, cleavage, and foliation surfaces, and commonly replaces garnet, amphiboles and pyroxenes. A rock pit near the airstrip shows the following paragenesis:

1. Unaltered pink garnets in both metasediments and pegmatoids
2. Pseudomorphed garnets partially to completely chloritized occurring in essentially unaltered as well as hematitic (not necessarily regolithic) pegmatoids
3. The change from dark green chlorite-garnet pseudomorphs to pale green chloritic pseudomorphs toward fractures characterized by pale green alteration
4. Pale green alteration cutting across fractures coated by the dark green chlorite.

The dark green chloritization is interpreted as in part due to retrogression accompanying mylonitization, probably coeval with hematization.

The pale green to white (hydrothermal) alteration consists of chlorite, sericite and epidote, along with clay minerals, some silicification and in places the formation of a white amorphous coating of tourmaline on quartz veins (Hoeve, pers. comm.). Much of the argillic alteration is fine grained, pale green to white chlorite and sericite, occurring in veins cutting the regolith as well as in hematitic shale horizons in the Athabasca Formation. Where the basement gneisses are strongly fractured and sheared, as in the ore zones, the alteration is most intense and in places the rocks are completely argillized.

Uranium Mineralization

The main mineralizing event in the Cluff Lake area apparently accompanied the period of hydrothermal activity at about 1100 to 1000 m.y. (Tapaninen, 1975, 1976; Herring, 1976; and Sibbald et al, 1976). Tapaninen (1975, 1976) and others have described the ore mineralogy of the deposits emphasizing the complex suite of uranium, gold, selenium, and base metals of the D ore body compared to the relatively simple mineralogy of the N and Claude ore bodies.

The following appear to have a bearing on the distribution of uranium occurrences within the Carswell structure:

1. The restriction of the known occurrences to the outer edge of the basement

massive, coarse to pegmatitic, and strongly stained by limonite caused by disseminations and veinlets of iron sulphides occurs within a sequence of limonite-coated quartzo-feldspathic rocks.

The pegmatoid rocks (Unit 6) are a "suite of coarse grained leucocratic rocks which have an apparent intrusive or vein-like relationship with the basement gneisses (and) to emphasize that, although they appear to be pegmatitic in origin the characteristics of true pegmatites are not well developed" (Herring, 1976, p.58). These pegmatoids generally contain garnets, pseudomorphed by chlorite, as a common accessory, but are generally free of mafic minerals.

The Cluff Breccias (Unit 10) include a wide variety of breccia veins and dykes ranging from a few millimeters to tens of metres thick and hundreds of metres long. Many of the smaller veins and dykes of pseudotachylite are devitrified and weather to a greyish-green amorphous argillic mass. The smaller dykes commonly contain a greater clast to matrix ratio compared to the larger dykes and/or flows. Clasts increase in size and abundance toward the center of a few dykes, but in most there is no zoning. Clasts vary from microscopic in size to tens of centimeters across.

The larger bodies of Cluff Breccia contain primary structures such as vesicles, amygdales, flow lines, and columnar joints, and textures including microscopic felty growth of feldspar in a glassy matrix typical of volcanic rocks. Fifteen samples of this type of Cluff Breccia were collected from three different areas for whole rock analyses. The results are summarized in Table 1 and shown graphically in Figure 2. Twelve samples collected from drill holes CAR 53 and CAR 57 cluster together on the AFM diagram indicating a melt of dacitic composition. The three samples collected from frost-heaved outcrop northeast of the ELF zone have a more felsic, rhyodacitic, composition. The K_2O-CaO-Na_2O plot is consistent for all the samples.

The cataclastic equivalents of the metamorphic rocks, tectonic breccias and mylonites, are rarely exposed because of their low resistence to weathering. The cataclasites vary from bands less than a centimeter thick to zones several meters thick and in a few places, mylonitized rocks are exposed over larger areas. The tectonic breccias contain angular, generally aligned fragments of the host rocks in a fine grained comminuted groundmass. Chlorite and veins of pseudotachylite are commonly developed in these zones.

The gneisses immediately underlying the Athabasca Formation are generally deep purple due to hematization. The clay profile described by Hoeve (this volume) from the Rabbit Lake area does not appear to be present in this weathered regolith.

core and to the sub-Athabasca unconformity.

2. The association of hematized basement rocks, either regolithic or the earlier retrogressive hematization.

3. The association of mineralization with quartzo-feldspathic and pelitic gneisses.

4. The abundance of Cluff Breccias in most of the occurrences.

5. The presence of graphite or carbonaceous matter in most of the occurrences.

The lack of ore bodies in the central portion of basement core may be due to erosion following differential uplift after meteoric impact. Radioactive occurrences are present in the central basement area but to date none have proven significant.

The association of uranium and hematite in the regolith is probably a function of greater permeability and a similar relationship appears also to be true in the hematised zones of retrogressive metamorphism.

Many of the uranium occurrences are associated with quartzo-feldspathic and pelitic gneisses. Two possible explanations of this relationship are: a) the presence of graphite and pyrite in these rocks, providing a reducing environment for the precipitation of uranium and b) a greater susceptibility to fracturing and alteration thus providing an increased permeability to circulating ground water or hydrothermal solutions. The pegmatoids are reportedly thorium-rich (Herring, 1976; Tapaninen, pers. comm.) and along with some of the red gneisses may have provided a source of uranium. Being more susceptible to leaching than thorium, uranium would be preferentially removed and transported in the aqueous environment to be ultimately reprecipitated in favourable physio-chemical environments (i.e. organic shales of the lower part of the Athabasca Formation).

Where there is uranium mineralization, Cluff Breccias are invariably present and commonly abundant although the existence of Cluff Breccias does not always indicate mineralization. This association suggests that some reworking of the mineralization may have occurred. As yet no pitchblende ages have been obtained tc substantiate this hypothesis. The Cluff Breccias, like the uranium mineralization, may have invaded already weakened zones.

Discussion

The basement gneisses of the Carswell structure are similar in many respects to rocks of the White Lake Complex north of Lake Athabasca (Koster, 1963 and 1967) and the Firebag and Western Granulite domains (Sibbald, 1974, and Lewry, 1974) south of the Athabasca Formation. Koster (1963 and 1967) and Koster and Baadsgaard (1970) indicate that the White Lake Complex may be derived from an older Archean basement complex which has been strongly overprinted by the Hudsonian. A granodiorite-diorite series of the older complex shows an average K-Ar age of 2370 m.y. (Koster et al, 1970).

To the south, the Western Granulite and Firebag domains are thought to represent an Archean granulite facies terrain mildly overprinted by the Hudsonian (Wallis, 1970, and Lewry and Sibbald, 1977).

The continuity of aeromagnetic patterns from the Western Granulite domain through the Firebag domain and Carswell area to the area north of Lake Athabasca (Wallis, 1970 and GSC Map 1255A) lends support to the above correlations. Therefore, it is possible that some of the rocks of the Carswell area are Archean and underwent moderate to strong overprinting during the Hudsonian.

The continuation of the present program will be dependent upon the mining of the various Cluff Lake ore bodies when the three dimensional aspects of rock types, alterations, and the kinds and controls of mineralization can be observed. Coupled with this is a need for further studies on a broader scale to tie together the structural and metamorphic histories of the western part of the Saskatchewan shield such that areas of potential uranium mineralization may be more closely defined.

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