GEOLOGIC SETTING OF POLONIUM RADIOHALOS

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INTRODUCTION

The existence of radiation-damage halos, also known as Radiation-Induced Colour Halos, or RICHes (Odom & Rink, 1989), in minerals has been known since 1907 (Joly, 1907, 1917). Histories of the study of these halos is given by Gentry (1988), Wise (1989), and Wilkerson (1990 in press). Interest in radiohalos and in particular certain varieties of Po halos has been revived by Gentry and others (Gentry, 1966a,b, 1968, 1970, 1971, 1973, 1974, 1978, 1979, 1986b, 1988; Gentry et. al 1973, 1974, 1976,1978).

The existence of Polonium halos in Precambrian "granites" has been interpreted as proof of the instant creation of the earth (Gentry, 1988). Due to the very short half life of one of the isotopes, Po-218, the length of time of this creation is interpreted to have been "less than three minutes (Gentry, 1986, p.34)". Po halos, according to this model, would be expected to be found in the oldest rocks of the earth's crust. Absent from almost all of these investigations is a documentation of the geology of sites from which Po halos have been described. There are no precisely-described specimen localities except for two --the Silver Crater Mine and the Faraday Mine near Bancroft, Ontario, Canada.

Wakefield (1988a,b) described the geology of these sites which shows clear incompatibility with this particular creation model. Here we present a synthesis of what is now known of the regional and local geologic setting of this and other Po halo sites. The geological complexity of the Po halo localities, specifically the Canadian Precambrian ones, the fact that the Po hosting pegmatites are definitely intrusive, and that sedimentary and volcanic successions pre-date Po halos are evidence against this creation model.

GEOLOGY OF POLONIUM HALOS

A) The Canadian Shield:

Two of Gentry's published locations --Faraday Mine and Silver Crater Mine--and one unpublished location --Fission Mine-- (Wakefield 1988) are located in the late Proterozoic Grenville Supergroup of the Precambrian Canadian Shield. The Precambrian is divided into two main eras: the Archean and the Proterozoic based on specific geological criteria. Each of these eras is subdivided into reconstructible events such as large scale metamorphic activity or sedimentary and volcanic deposition.

A great deal of work has been carried out on the Precambrian Canadian Shield. The Shield is made up of seven distinct geological "Provinces" --west to east from the Northwest Territories to Quebec and in an arc around Hudson's Bay: the Bear, the Slave, the Churchill, the Superior, the Southern, the Grenville, and the Nain. Ontario, where Gentry's samples came from, includes three of these provinces. The Superior, situated in northern Ontario, is the oldest (all isotopic ages are greater than 2,500 Ma and hence is Archean) both radiometrically and structurally. It consists of many types of metasediments and several types of metavolcanics intruded by a variety of igneous bodies. The Southern Province, which rests unconformably (with fossil soil, Robertson (1968)) on the Superior, is mostly folded metasediments intruded by some granites and is middle to early Proterozoic (all isotopic ages are between 2,500 to 1,800 Ma) in age. The Grenville, located in southern Ontario, is the youngest Province and is late Proterozoic (all isotopic ages are 1,500 to 900 Ma). It consists mostly of deformed metasediments in the north, a large metamorphosed intrusive gneiss complex (called the Algonquin Batholith) in the middle, and the Grenville Supergroup in the south.

The Grenville Supergroup, which contains Gentry's locations, is a very complex succession of metasediments, metavolcanics, alkalic intrusive rocks, mafic intrusive rocks and granitic intrusive rocks. It is located in a region of low- to very high-grade metamorphism that has altered many of the igneous, sedimentary and volcanic rocks into gneisses. Many original igneous, sedimentary and volcanic features are preserved. Hydrothermally altered rocks and metasomatic rocks (wall-rocks that have been included within and altered by intrusive melts) are common. The metavolcanics, called the Tudor Formation, (the lowermost rock units in the Supergroup) consist of pillow lavas (indicative of underwater extrusion), breccias (fragmented lavas), tuffs and pyroclastics (similar to what came out of Mt. St. Helens), all altered to varying degrees by metamorphism. The intrusive rocks consist of varying types like gabbros (a dense rock high in the mafic minerals which contain iron and magnesium), granites (light-coloured rocks low in mafic minerals but high in potassium and sodium silicates like feldspar and quartz), diorites (intermediate in composition between the former two), syenites (poor in quartz), nepheline syenite (like syenite but higher in alkali metals and lower in silica), and pegmatites (any of the above in small dikes with large to very-large crystals). Many, but not all, of these intrusive rocks have been altered by low-grade metamorphism.

Many of the metasedimentary rocks, called the Hastings Formation, show clear and unambiguous sedimentary features like clastic grains, cobbles, ripple marks, mudcracks, bedding plains and, most important, stromatolites --fossil blue-green algal mats and domes.

Discussions defending the Po halo creation interpretation have denied the authenticity of the stromatolite fossils found in this area (Gentry, 1988, p.326). One reference, Hofmann (1971), has been taken out of context to show that there is no consensus on that interpretation. Hofmann specifically noted:

"A reconsideration of the evidence for a stromatolite hypothesis is in order. The gross morphology, internal structure, distribution pattern, marker laminae, and bulk lithology are very much like a great many stromatolite occurrences in undeformed Proterozoic carbonate sequences. What distinguishes those at L'Amable is the coarse grain size, the non-regularity and large spacing of the darker laminae, and the deformed (squeezed) nature, all of which could be attributed to the effects of high-grade metamorphism. The notion that a relatively little deformed remnant of marble should be preserved in a more severely squeezed, plastically deformed belt need not invalidate the stromatolite interpretation,...

In addition, there are abundant outcrops showing well-preserved primary bedding (Hewitt and James, 1956, pp.19,21), so it is possible to have a favourably situated block containing remnants of primary sedimentary features. ...

Although a stromatolite origin for the original structures at L'Amable is reasonable, it is not considered proven (Hofmann, 1971)."

We must not get confused here. Hofmann is describing only one stromatolite occurrence --the one at L'Amable a few kilometers south of Bancroft. There are many other locations, mostly in the much less deformed areas south of Bancroft, which have well defined stromatolites. The stromatolites from Belmont Lake island (Figure 1) are undeniable. The L'Amable ones are not as good due to the higher metamorphic grade of the area.

A more recent publication describing stromatolites in all the localities noted:

"Biosedimentary structures preserved in the rocks of the map area and other parts of the Central Metasedimentary Belt [of which the Supergroup is part of] are stromatolites, ...

Stromatolites in the Burleigh Falls-Bancroft-Madoc area comprise five main types, distinguished by variations in morphology. In ascending order of morphologic complexity these are: (1) algal laminates (mats); (2) domal stromatolites; (3) columnar stromatolites; (4)conophyton forms; and (5) jacutonphyton forms. ...

In general, mid-amphibolite facies recrystalization is not, without moderate to strong deformation, sufficient to prohibit recognition of stromatolitic structures. ...

The ubiquity of stromatolites in the map area provides well constrained evidence that the prevailing depositional setting consists of one or more relatively extensive carbonate platforms. [Bartlett and DeKemp (1987)]"

They note that the setting for these stromatolites in dolomitic marble would indicate a "shallow marine environment" with some of the sedimentary rocks showing turbidite series. The pegmatites and vein-dikes which contain the Po halos are STRUCTURALLY YOUNGER than these depositional rocks.

Stromatolite fossils differ slightly from other fossils in that it is not the actual organisms which are preserved as rock, it is the structures of detritus these organisms form into their mounds which are preserved. However, this does not detract from the inference derived by comparison with living versions. Hofmann (1987) describes many other Precambrian fossils which also predate Po localities.

The Fission (also known as the Richardson) Mine is located 2 km east of Wilberforce on lot 4, concession XXI, Cardiff Township (Lat. 45o3'15"N; Long. 78o11'40"W, Figure 2) and consists of a single abandoned adit driven into a hill. This site is a common mineral-collecting locality for apatite, biotite, radioactive minerals, and fluorite.

From the description in Hogarth et al (1972) it is clear that this is a small calcite vein-dike (a rock containing mostly large crystals of calcium carbonate and other minerals like mica) body. The biotite grew outward, replacing the calcite, from the syentized wall-rock as a result of reactions between the wall-rock, calcite core and volatile fluids (Moyd, Personal Communication, Aug. 1987). This vein-dike is small in length and width, it cuts metasedimentary rocks which still retain bedding planes, and radioactive minerals abound. In another mineral collecting guidebook it was noted that at this site "Uraninite was found in cavities in pegmatites with magnetite, mica or calcite-fluorite intergrowths." (Sabina, 1986, p.79). Clearly radioactive minerals occur in this locality.

The Silver Crater (Basin) Mine is located 12 km west of Bancroft on lot 31, concession XV, Faraday Township (Lat. 45o01'50"N; Long. 78o00'30"W) 3 km north of the settlement of Monck Road (Figure 2). This abandoned mine consists of an adit with some drifting and a raise. The calcite vein-dike body here was mined for its biotite content. This is the locality of the mica that contains Gentry's 'spectacle' halo which "...exhibits true radiohalo characteristics.". This site is similar to the Fission site and the calcite vein-dike is part of the same group of calcite vein-dikes dotting the country side near Bancroft. A full description of the relative geological setting of this site can be found in Hewitt, (1957).

Contrary to Gentry's general claims, the rock types at the Silver Crater and the Fission Mines are not granites. The composition and mode of origin is totally wrong for a granite. Recent research about the origin of the calcite vein-dike material, due to the presence of rounded calcite in the biotite and other large minerals in the dikes, indicates that the biotite grew as a replacement within the solid calcite vein-dike matrix. This process occurs when the solid calcite vein-dike (which was hydrothermally deposited, or injected as a molten liquid) is reheated enough to cause the evenly distributed minerals of biotite, hornblende, betafite, apatite, etc. in the wall-rock and calcite vein-dike to start to migrate and form larger crystals in the calcite vein-dike (Moyd 1989).

The Faraday (now called the Madawaska) Mine is located 5 km west of Bancroft on Highway #28 on the north-east end of Bow Lake (Lat. 77o55'30"N; Long. 45o00'15"W, Figure 2). The mine workings consisted of several adits, drifting and several levels. Figure 3 shows the surface geology at this site. The mine was opened for the uranium in a granite pegmatite, which cuts a gabbro/metagabbro intrusive body 10 km long and 1.25 km wide, which itself cuts metasedimentary rocks, mostly marble.

The history of events recorded in the rock record witness material eroded from some preexisting rock, deposited as a sedimentary rock (probably a volcanic arc island setting (Easton, 1986b)), then deformed and recrystallized by high-grade metamorphism (referred to as the Grenville Orogeny (Lumbers, 1982)) which changed this rock to paragneisses. This in turn was intruded by the gabbro, which later underwent another metamorphic episode during the latter stages of the orogeny. Finally, these rocks were intruded by the granite pegmatite. The biotite which hosts some of these Po halos came from this pegmatite. The pegmatites are 91.5 to 915 meters long, 3 to 46 meters wide and some extend down dip more than 300 meters. (Masson and Gordon, 1981, p.60). This entire sequence was then altered by fluid migration called fenitization, introducing calcium altering the chemistry of the rocks in the area (Lumbers, 1988 personal communication).

A.R. Bullis writing on the geology of the Faraday mine notes the structure of the pegmatites: "...in other places [the pegmatites] are discordant and show cross-cutting relationship to all of the wall-rocks. The contacts are sharp and clear cut and others are in the nature of irregular, gradational zones that show a change, or alteration, from paragneiss to granitic pegmatite over widths of up to 24 inches. It is obvious that both injection and metasomatic processes have taken place during the intrusion of the pegmatites. Chilled edges are rare or non-existent. Magmatic stopping, or the engulfing of the country rock has taken place on a large scale; there are many blocks of paragneiss and pyroxenite within the pegmatite [xenoliths]. Most of the inclusions are fresh looking, but many are highly altered and ghost-like in appearance (Bullis, 1965, p.717)."

All three Bancroft sites, and many others, are uranium localities. Some, including the Faraday pegmatite, were mined for uranium. Four million tons of ore was mined from the Faraday for 3.3 million kg of uranium oxide until it closed in 1984. The average concentration consisted of 0.1074% uranium oxide. The most common radioactive mineral is uranothorite, hence plenty of uranium and thorium were present. These minerals are very small (less than .1 mm) and scattered throughout the pegmatite becoming ore grade in the quartz and magnetite regions of the pegmatite.

The Silver Crater and Fission mines are lithologically different, but they too contain abundant radioactive minerals --especially betafite (a radioactive variety of the mineral pyrochlore, which is a complex calcium-sodium-(uranium)-niobate- tantalate-hydroxide). It was noted by Satterly that "Betafite [at the Silver Crater] is often found in close association with clusters of mica books and apatite crystals. Small crystals of betafite have been found within the books of mica. (Satterly, 1957, p.130)"

Figure 5 diagrammatically shows the geological relationships of part of the Shield and the location, in relation to the geology, of Gentry's Faraday samples. These relationships are not based primarily on the "uniformitarian principle" but on hard-won field observations over almost 100 years of work by thousands of geologists. At the bottom-left of the figure is a block diagram of Figure 3. The pegmatite dikes cut a gabbro (shown at the bottom right), which cuts different types of metasedimentary rocks. These metasedimentary rocks can be shown, in the field, to rest in a complex way on metavolcanics around the Madoc area south of Bancroft (middle block). This, in turn, rests unconformably on the metamorphosed Algonquin Batholith, which intrudes the deep- and shallow-water metasediments to the north (top block), which abuts (by a major fault) and partly rests on the metasedimentary column of the Southern Province, which rests unconformably on the "greenstone" metasediments and metavolcanics intruded by granites, which abuts the metasedimentary and gneissic belts to the north in the Superior Province. So if Gentry's claim of created granite is valid, then this entire sequence also must have been instantly created--in "just three brief minutes". Since these Po halo dikes are demonstrably the last rocks to form in the Shield then, by his reasoning, the entire Shield must have been "instantly created".

It would help now to understand what geologists define as a pegmatite: "Pegmatites represent the final water-rich, siliceous melts of intermediate to silicic igneous magmas, and can generally be thought of as final residual melts... Although pegmatites can be found in almost any shape, they are most commonly dike-like or lensoid. Most pegmatites are small, but dimensions can vary from a few meters to hundreds of meters in the longest dimension and from 1 cm to as much as 200 meters in width. ... Since igneous pegmatites characteristically solidify late in igneous activity, they tend to be associated with plutonic or hypabyssal intrusions from which the volatile fractions could not readily escape. The great majority of pegmatites developed in deep-seated high-pressure environments (Guilbert and Park, 1986, p. 488)."

There are 4 basic types of pegmatites: simple zoned, complex zoned, simple unzoned and complex unzoned (most U/Th mineralization in the Bancroft area is in this type). The simple types are original and unaffected after emplacement. The complex type show various stages of alteration after solidification. The zoned pegmatite dikes show clear mineralogical zoning from the edges to the core of the dike due to the inability of the fluid to lose volatile components. On a highway rock cut just north of Buckhorn, west of Bancroft, a small zoned pegmatite, with 4 to 8 inch sized biotite and uranium mineralization, contains polonium halos (Collins, 1989, personal communication.) Zoned pegmatites are common in the Supergroup. The unzoned pegmatites cool much more quickly due to the loss of volatile components during crystallization of the melt. The grain size of zoned is generally greater than the unzoned.

The Faraday Mine pegmatites are considered a complex unzoned type (Masson & Gordon, 1981) where the pegmatite has undergone post-magmatic alteration involving deformation, hydrothermal activity and metasomatic reactions with the wall-rock. The uranium enrichment in the pegmatites is a two-stage process of a primary magmatic concentration and a secondary, later, concentration due to fluids picking up U and Th from both the pegmatites and the wall-rocks (mostly the syenites). Subsequently the U and Th minerals are precipitates. Masson and Gordon (1981) note that there are 5 principle controls for U deposits in the Bancroft area. 1) Premetamorphic concentration of U in the sedimentary deposits of the Supergroup. 2) High-rank regional metamorphism (the Grenville Orogeny). 3) Regional deformation of the country rocks causing fractures and openings for the emplacement of the pegmatites. 4) The proper geochemistry of the country rocks for mobilization of uranium, such as syenite and marble. 5) Large granitic bodies near by for the remelting and production of the magma, during the latter stages of regional metamorpism, for the pegmatites.

There are many types of dikes, other than pegmatites, that cut the other rock units of the Shield. In northern Ontario the most common of these are diabase dikes, which are found in very large clusters called dike swarms. Diabase dikes are narrow (from centimeters to many tens of meters) and very long (kilometers to hundreds of kilometers). Some dikes are fine-grained at the contact with the wall-rock and grade to course-grained in the centre. In the Sudbury area some of these dikes are known to cut through over 30 other rock units (Pye, et al, 1984) In the Archean area of the Shield at least 4 different sets of different-aged diabase dikes cross-cut each other (Fahrig & West 1986).

Some dikes have a clear-cut, or chilled, contact with the wall-rock, while others have a gradational contact because the heat of the intrusive dike partly melted the wall-rock. This occurs in the pegmatite at the Faraday Mine. And some of the dikes are vein-dikes deposited in cracks or cavities by fluids. This is the case with the Fission and Silver Crater sites. Just about all reports where pegmatites and other intrusives are described, there exists xenoliths. Xenoliths are pieces of wall rock which have broken off and caught up in the melt. Many of these exist in the Faraday mine pegmatite.

Based on the physical relationships of the rock sequences, it seems unreasonable to consider that polonium halos show instant creation of the earth. There is just too much pre-existing rock with clear evidence for a complex series of depositional, intrusive and metamorphic events to accept Gentry's "creation model."

B) Grain size and creation:

The grain size of minerals is also supposed to be an indicator of created rocks. According to Gentry, large crystals cannot form naturally (Gentry, 1986, p.131, 301). However, evidence from the geological record reveals this is not the case. It is not uncommon for dikes and plutons to show a gradation in crystal sizes from microscopic at the contacts, to pegmatitic in the core. Also intrusive rocks known as porphories, which contain very large crystals in a fine-grained matrix, contradict this model (Wilkerson, 1990 in press). Igneous rocks with both large and small grain sizes both predate and postdate the Po-halo bearing (e.g. "created") rocks.

C) Geologic Setting of other Po Halo Occurrences:

A listing of Po halo localities has been given by Wise (1989) and Wilkerson (1990 in press). Po haloes are known from Canada, Scandinavia, Japan, Madagascar, United States and Germany. The halos occur in rocks from Precambrian to Tertiary age. All are related to uranium/thorium mineralization. Some occur within the mica of pegmatites while others are found within accessory minerals in vein deposits. Several Po-containing mineral deposits cut across (and hence are younger than) fossiliferous host sediments.

MICROSCOPIC OBSERVATIONS

Thin section analysis of Po halos show that they are concentrated along fractures and cleavage planes (York, 1979). Photographs of Po halos often show the same diameter, indicating that all are within the same plane (Wilkerson, 1990 in press).

Several Po halo deposits show mineralogic replacement textures both in the mineralized zones (Wakefield, 1988a,b) and in the host rocks. At one of the Polonium halo sites, the Silver Crater Mine in Ontario, the biotite exhibits mineralogic and stratigraphic relationships that indicate a secondary origin. These vein-dike deposits show evidence of crystal growth by replacement of pre-existing vein-dike material. Such crystals contain within them relics of the original rock. The country rock also show clear signs of alteration. The alteration is probably due to circulating fluids simultaneously dissolving some minerals and replacing them with others.

The "Spectacle Halo" (Gentry et al, 1974) gives clear evidence for migration of Po-210 radiocenter along fractures and around spherical dislocations in a biotite crystal lattice (Wilkerson, 1990 in press).

In some specimens, there is an overlapping of Po and U halos (Gentry et al., 1986, fig. 1). In order to account for this observation and still maintain a young-earth interpretation, the ad hoc assumption must be made that decay rates varied many orders of magnitude in the past (Gentry 1988 p. 316, 317). If radioactive decay rates have been constant, as all existing experimental evidence suggests, then very long periods of time must be required for both Po and U halo formation (Brown, 1986).

Some Po halos are deformed (Gentry et al., 1976). Elliptical (deformed) and spherical (undeformed) are known from the same Po inclusion (Gentry et al, 1976, fig. 3). These observations indicate that Po halo generation is an on-going process that both pre-dates and post-dates deformation of their host rocks. Their formation involves a non-instantaneous series of events.

ISOTOPIC OBSERVATIONS

The other line of evidence in support of a natural origin for the Polonium halos is in the fact that every location were these halos are found, there exists abnormally high uranium and/or thorium concentrations. The Po halo sites in Ontario were mined for uranium (Wakefield, 1988a,b). The Conway granite, a Po-halo source, has been proposed as a commercial source of thorium (Richardson, 1964; Richardson and Adams, 1964).

A secondary origin of Po halos is suggested by the fact that selenium (Brown, 1986, Gentry, 1986, 1988 p.318) and uranium (Gentry, 1971, Wilkerson, 1990 in press) exist in some Po radiocenters. Since selenium has no radioactive origin, it must have been precipitated (and formed with) the Po through chemical reaction.

CONCLUSIONS

Summarizing the geology of the Po halo sites: 1) The samples of biotite that contain Po halos come from pegmatite dikes and calcite vein-dikes that cross-cut metamorphosed volcanic, sedimentary and igneous rock units --the dikes are clearly the last to form, not the first. 2) These dikes are not the vast extensive granite gneisses Gentry claims are the backbone of the mountains and continents --they are relatively small features. 3) Two of the sites are not even granites but calcite vein-dikes, most likely of hydrothermal origin. The biotite was formed in the solid matrix by metamorphism and metasomatism. 4) Crystal size variation in igneous, vein and metamorphic rocks is primarily due to cooling rates and crystal growth, and cannot be used to identify "created" rocks.

The sequence of rock units in the Bancroft/Madoc area is summarized in Figure 4. Formation of Po halos was one of the last events to occur in this area since the pegmatites are last. If the Po halo creation model were true, then a creation of rock with features known to have natural explanations would be required. Such a creation of apparent history would be so extensive as to make Phillip Gosse meek in comparison.

The available geologic data from other Po halo sites also indicates that they are components of relatively young mineral deposits within older host rocks. Rocks with Po halos are NOT the oldest (e.g. created) rocks of the earth's crust.

The origin of Po halos must involve a mechanism whereby Po is segregated from its U and Th precursors. This mechanism must result in concentration of Po haloes along fractures and cleavage planes. It must explain the simultaneous formation of Se with the Po.

One such mechanism is isolation or "orphanage" of uranium/thorium daughter products from U/Th precursors through radon accumulation and migration. Inclusions of radon at flaws in a mineral's crystal lattice would result in Po halos without the rings diagnostic of uranium or thorium precursors. There are several lines of evidence supporting a U-rich fluid migration precipitating the Po (probably via radon) which then produces the halos. 1) Po halos apparently occur in areas of unusually high uranium mineralization and metamorphism. 2) There are no halos for the thorium decay chain, even though the Th to U ratio is over 5:1 in the Faraday pegmatite, due to the insolubility of Th compounds (Brown, 1987). 3) No halos have been found in lunar rocks. 4) The geology of the mine sites listed above have different origins (magmatic -Faraday pegmatites- and hydrothermal -Silver Crater/Fission) suggesting that the halos can form in a variety of geologic environments, but that common to all of them is secondary migration of U/Th daughter products through fluid migration which has been shown to have occurred extensively in the area (Lumbers personal communication 1988, Lorence Collins personal communication 1990). 5) The U mineralization is primarily a precipitation (mainly in mafic minerals like biotite) in a reducing environment near the contact of the wall-rock and in fractures and cleavages in the case of the Faraday pegmatite (Masson & Gordon, 1981). 6) Oxygenated fluids rich in fluorine, phosphorus, and carbon dioxide readily dissolve uranium and increase the fluid's mobility (Masson & Gordon, 1981). And 7) polonium found in soil samples, migrated via radon, is used in prospecting to discover underlying uranium mineralization (Card & Bell, 1980).

We conclude, therefore, that Polonium halos are not some kind of "mystery" to science at all. The complex geological features the Po halo are hosted in indicates that it is unreasonable to invoke supernaturalism to explain Po halos. The available evidence strongly suggests a secondary origin.

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Figure 1. Stromatolites on an island in Belmont Lake, Ontario. These are in sedimentary rock structurally older that the Po containing pegmatites some 35 kilometers to the north.

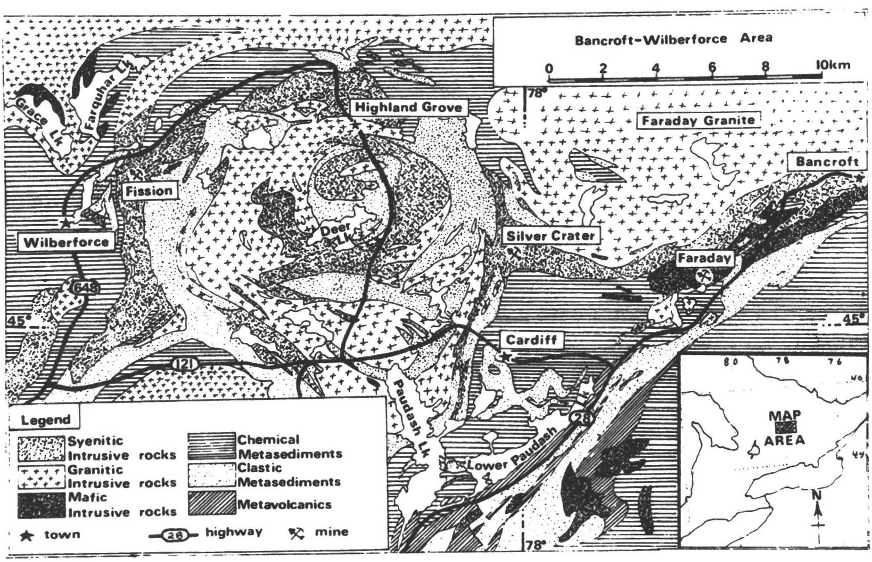

Figure 2. Basic geology of the Bancroft area showing the three mine sites where Po halos were observed.

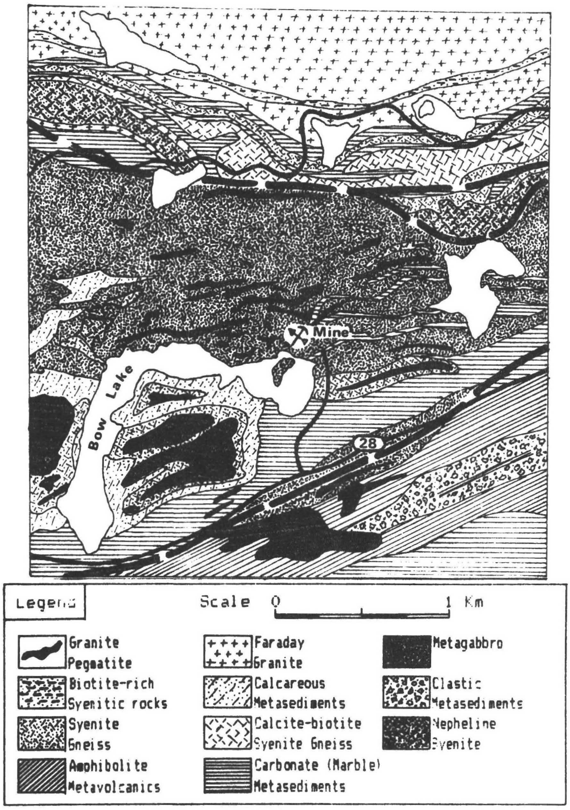

Figure 3. Detailed geology of the Faraday Mine. The Po halo containing pegmatites are long thin features crosscutting a series of rock units including marble.

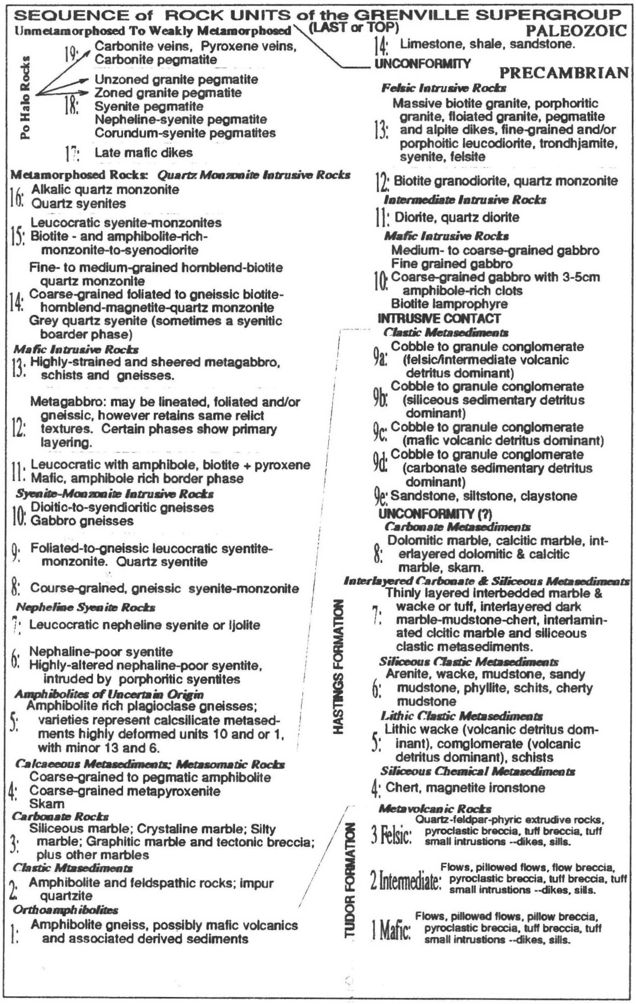

Figure 4. Stratigraphic succession of rock units of the Bancroft (left) and Madoc (right) area, from OGS Preliminary Maps P.2524 (1984) and P.2488 (1982)

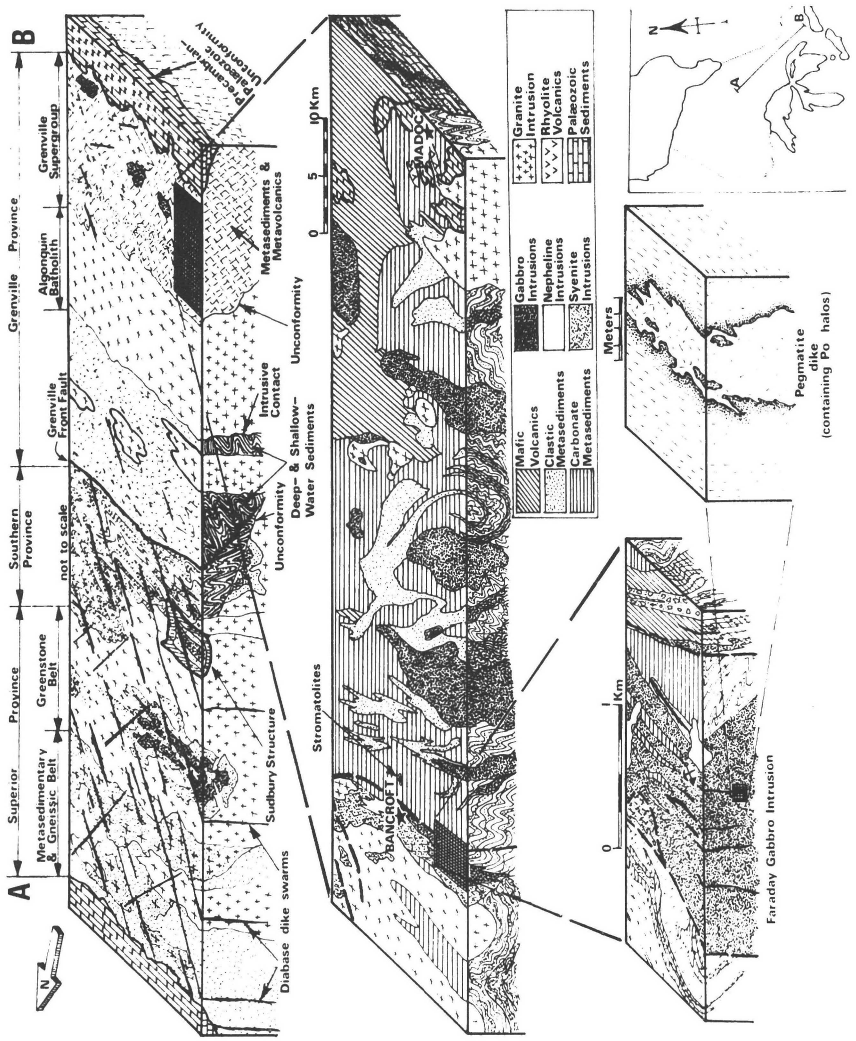

Figure 5. Diagrammatic representation of the Canadian Shield through the Bancroft area. The upper block is a cross section through the three provinces which make up this portion of the Shield. In succession the oldest rock unit is the Greenstone Belt area of the Superior Province. The Greenstones are successive volcanic and sedimentary units intruded by granites, which in turn intruded by diabase dikes. The Southern Province rests uncomformably on the Superior. This province consists of a large sequence of sedimentary rock units intruded by various intrusive rocks. The Sudbury Structure is a very complex entity (evidence supports an astrobleme) consisting of fall-back breccia, varved sedimentary sequence, grading intrusion and surrounding rock fracturing including shatter cones. This whole structure cuts both the Superior and Southern, but is itself deformed, and then cut by the diabase dikes. Separating the Southern from the Grenville is a major fault complex. The Grenville Province is a series of sedimentary rocks, with many intrusive bodies, some quite large like the Algonquin Intrusive Complex. The Grenville Supergroup is one of many complex substructures within the Grenville. The middle block represents a section through the Madoc/Bancroft area. The succession of rock units of this sequence is in Figure 4. The left lower block is of Figure 3, while the right lower block shows the relationship and structure of the pegmatites with the gabbro. The gabbro is an intrusive body into marble and other metasedimentary rocks.

If the Po halos creation model were true, then the entire Shield sequence of complex volcanic, sedimentary and intrusive rocks were created, in a three minute span, in a sequence which appears to be a long complex succession of deposition, erosion and intrusion.

DISCUSSION

The authors provide valuable data on the geologic conditions in which radiohalos occur. The authors correctly conclude that in many cases radiohalos occur in rocks which have formed by geologic processes and have been altered by geologic processes. This work will be a valuable addition to the literature responding to the conclusion of Dr. Gentry. Radiohalos do occur in rocks formed by igneous processes.

Steven A. Austin, Ph.D.
San Diego, California

The authors' comprehensive description of some of the halo sites is much appreciated. Although they claim it, their evidence for a secondary origin is in concert with uniformitarians of the past, and can only be justified by their strong dependence on the uniformitarian model. A creation model does indeed require massive short-time rock formation. The eyewitness account reports the world inhabited by the sixth day.

The halo circumstances are accurate - high local radioactivity, a gaseous immediate precursor, natural cleavage in mica, solubility ow Uranium and Polonium - all understood by Dr. Gentry when he started his unsuccessful search for a viable mechanism for secondary Precambrian ^{218}Po halos. The authors fail, however, to recognize that the unmistakable secondary halos which Dr. Gentry, happily, found in coal have distinct differences from the Precambrian halos, so that the mechanism cannot be rationally transplanted. The Selenium is indeed in these secondary halos. I suggest that the authors be more careful to delineate between ^{218}Po and ^{214}Po for which neither they nor anyone else has modeled secondary halos, and ^{210}Po, for which they have been observed.

William M. Overn, BSEE
Minneapolis, Minnesota

To establish that the Polonium (Po) halos are in rocks younger than those containing fossils (e.g. bacteria), would invalidate Gentry's model for the primordial (creation) origin of radiohalos. In spite of requirements to the contrary, however, (Gentry, 1988, 1989), Mr. Wakefield and Dr. Wilkerson have established neither the biogenic nature of the stromatolites, nor a continuous, unbroken contact between the Po-containing rocks and the fossils.

Though Mr. Wakefield and Dr. Wilkerson make much of the Precambrian history written in the rock, Gentry (1988, 1989) has made it clear that such history means little to him, as God can create it that way with little "difficulty". It has not been demonstrated that Gentry is wrong on this point.

The natural origin of Po halos is suggested by the evidence - it is not as firmly established as Mr. Wakefield and Dr. wilkerson seem to indicate. Po halos in crystalline rocks have not been produced naturally in experiment and no viable hypothesis has surfaced for the precise process.

Mr. Wakefield and Dr. Wilkerson's argument for the natural hydrothermal origin of radiohalos is not as powerful as it could be (1). Besides the fact that Po halos are found along fractures and cleavage planes (noting that any position in a biotite crystal is close to a cleavage plane), evidences include: Po halos are found only in minerals which can be produced hydrothermally; the only Po isotopes known as halos are only those Po isotopes known from the decay series of Uranium (U) and Thorium (Th); the concentration of Po halos may be related to the concentration of Uranium in the rock; Po may not be found within the crystalline matrix as is U and TH (Meier and Hecker: 1976:188).

Mr. Wakefield and Dr. Wilkerson's paper provides very little increase in information over previously published papers (e.g. Wakefield, 1988 a,b), and seems to ignore some pertinent works (1 [incorrectly referenced], 2) and fails to pursue many possible fruitful lines of inquiry on the subject, such as verifying the claims of the previous paragraph.

1. Wise, Kurt, P., 1989, "Radioactive Halos: Geological Concerns", Creation Research Society Quarterly 25 (4):171-176.

2. Gentry, Robert, V., 1989, "Response to Wise", Creation Research Society Quarterly, 25 (4):176-180.

Kurt P. Wise, Ph.D.
Dayton, Tennessee

CLOSURE

Response to Dr. Steven Austin:

Dr. Austin and one of us (Wilkerson) participated in a debate about the age of the earth at the 1990 ICC Conference. As geologists we understand and apply the basic principles of superposition, original horizontality, and cross-cutting relationships to our work. On the basis of these principles we concluded that Po radiohaloes are the last things to form in the uranium deposits that host them. This is a very simple deduction based on logical principles and stands on its own merits apart from assumptions about process rates or the age of the earth. Young-earth creationists will do well to abandon Gentry's arguments for a young earth and for instantaneous creation of Po haloes.

Response to Mr. William Overn:

The Silver Crater, Fission and Faraday uranium deposits we investigated contain Po-210, Po-214 and Po-218 halos. Our conclusions apply to all of these Po halo types, since all of them are known to exist in these deposits. The halos are younger than the fractures along which they form. The fractures in the biotite are younger than the biotite. The biotite is younger than the calcite which it replaces. The calcite vein-dike is younger than the wall rocks which host them. Our deduction of a *sequence of events* for all Po haloes takes into consideration data which we feel Gentry has marginalized or ignored.

It is not necessary (as Mr. Overn suggests) to have experimental evidence or even a model for Po halo formation to demonstrate that Po halos are not primordial. Our argument is based on the logic of cross-cutting relationships, not on uniformitarianism. We object to the habit that young-earth creationists have of discounting contrary opinion only on the philosophical grounds of anti-uniformitarianism. We are not uniformitarians, we are actualists and insist only that geologic observations be interpreted in the light of known physical laws.

Mr. Overn's phrase "The eyewitness account reports the world inhabited by the sixth day" shows that he, as a young-earth creationist, objects to our actualistic interpretation mainly because of a pre-conceived theological mind-set. No amount of empirical data will ever change the mind of persons committed to such a religious belief.

Response to Dr. Kurt Wise:

We believe that the stratigraphic record of the Precambrian in the Bancroft area is sufficiently well known to demonstrate a continuous series of geologic events between stromatolite localities and the Po halo-containing uranium deposits. The stromatolites nearest the uranium deposits we investigated are in the Hastings Formation and are deformed. Because of this deformation the identification of them as biogenic has been questioned. In our presentation we showed photographs and gave descriptions of undeformed stromatolites from the Hastings Formation 20 km south of Bancroft at Belmont Lake. Dr. Wise makes the assertion that the stromatolites we cite are not of biologic origin despite their oval shape, attenuated layering and carbon content--precisely what would be expected if they were metamorphosed algal colonies. He objects to our interpretation, yet he offers no non-biologic explanation for their origin. We know of no non-biologic mechanism that could produce these structures that resemble so closely unaltered algal colonies.

Dr. Gentry's ad hoc attempts to fit his theory into the known geologic and mineralogic details of the uranium deposits we studied lead to several illogical conclusions (Wilkerson, 1991 in press). The trouble with Dr. Gentry and other young-earth creationists is that, regardless of the evidence for a sequence of events, one can always say "God made it that way". So Gentry will, of course, find "little difficulty" in incorporating our data into some variation of his "model". That's O.K. for a believer, but for the skeptic it just won't wash.

Our work summarized data for the first time--and from a variety of sources--data which indicate that Po radiohaloes must have formed as orphaned isotopes, separated permanently from their radioactive parents. Wise's contention that a hydrothermal origin for Po halos be questioned because "Po halos in crystalline rocks have not been produced naturally in experiment..." is flawed. The argument is a common creationist tact and implies that experimental duplication is the only way to deduce scientific truth. Such a narrow view of scientific truth is not held by us. The argument also ignores the thermal requirements of uranium deposit, metamorphic and igneous rock formation which require lots more time than young-earth "creation models" can afford.

In our paper we do not advance a model for Po halo formation. We only show that there are very tight mineralogical and geological constraints that all models must incorporate. It seems more reasonable to us that Po was separated (orphaned) from U and Th parents by the migration Po precursors (Ra, Rn, Bi) than that they were created with an appearance of age. In order to accommodate our data and also keep a young-earth view, creationists will have to erect additional ad-hoc hypotheses such as variations in radioactive decay rates.

Richard Wakefield
Gregg Wilkerson, Ph.D.