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8. POLONIUM HALOS AND MYRMEKITE IN PEGMATITE AND GRANITE

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Introduction

During development of theory on the origin of myrmekite, I became aware of an interesting application of these studies to the seemingly-unrelated enigma of polonium ("Po") halos.

Whereas most geologists have long accepted a "magmatic" origin for large granite plutons, "batholiths" in which crystallization is imagined to have been attenuated over millions of years (Leake 1990), their magmatic view was technically challenged by Robert Gentry, a physicist with a yen to confirm the biblical tale of Genesis (Gentry 1965, 1970, 1974, 1983, 1988). He suggested that the Po halos, which are found in the minerals biotite and fluorite in granites and associated pegmatites, prove that the host rocks were created, not from magma, but almost instantaneously during Day 1 of the Genesis Week.

The radioactive elements emit particles of varying energies. Po halos are zones of atomic disarrangment caused by alpha particle emission. It is self-evident that the emitted particles must be younger than the granite minerals, biotite and fluorite, in which they occur. The radiating particles take paths that pass through neighboring minerals. Having varying penetrative powers, various particles produce characteristic radial zones of destruction that are diagnostic of particular decaying elements (Fig. 1).

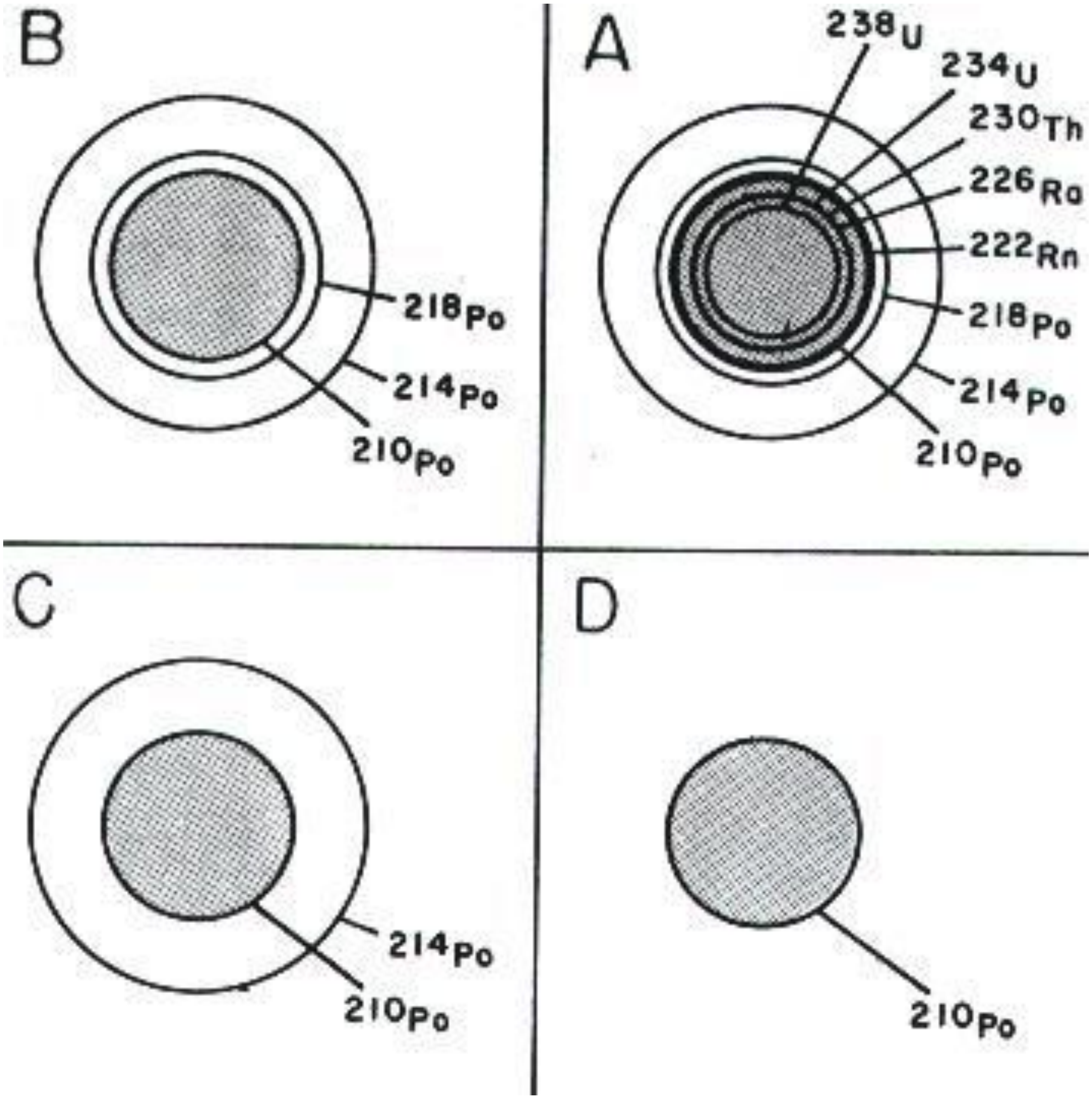


Fig. 1. A. Schematic drawing of ^{238}U halo with radii proportional to ranges of alpha-particles in air. B. Schematic drawing of ^{218}Po halo. C. Schematic drawing of ^{214}Po halo. D. Schematic drawing of ^{210}Po halo (from Collins, 1988).

Gentry advanced six premises having to do with the radioactive behavior of Po, on the basis of which he reasoned that, if the time for the granite and late-stage pegmatites crystallize were millions of years, then regardless of the original quantity of polonium isotopes in the magma, their lives would be too short for any to have remained for the final crystallization of biotite and fluorite. Gentry is thus arguing that Po could not occur at all in the minerals where the Po halos are found.

Gentry's six premises are:

(A) Polonium isotopes (^{218}Po, ^{214}Po, and ^{210}Po) are the last three of eight decay products that are formed when ^{238}U radioactively decays to ^{206}Pb.

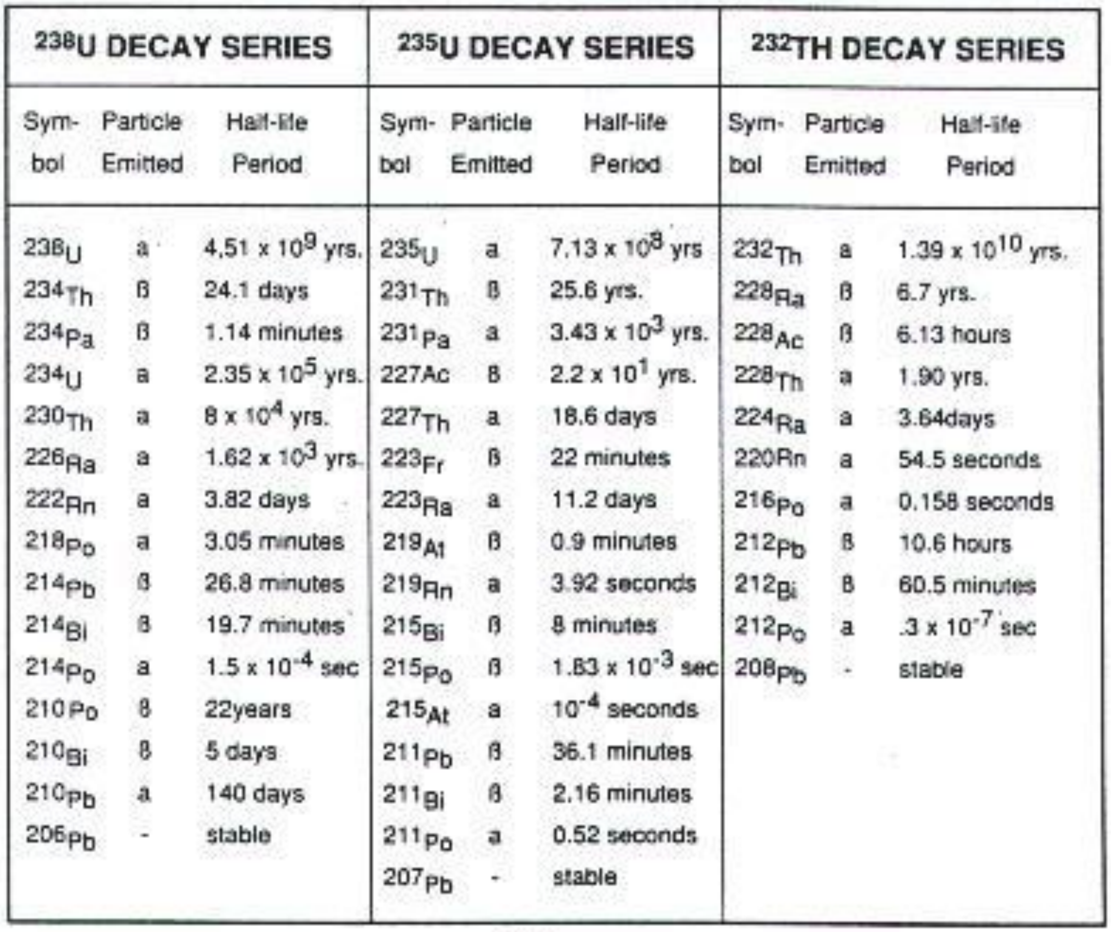
(B) The half lives of the three polonium isotopes are relatively short: ^{218}Po = 3.05 minutes; ^{214}Po = less than 200 microseconds; and ^{210}Po = 140 days (Table IV-8).

(C) The decay of each isotope produces alpha particles, the radial ejection of which damages the lattice structures of biotite and fluorite creating visible spherical shells (rings in two dimensions) of damage.

(D) The radii of these rings are proportional to the energies of release of the alpha particles, are different among themselves, and hence, distinguishable for each isotope Fig. 1.

(E) A concentration of 10^8 to 10^9 decayed atoms is needed to create visible damage rings.

(F) Absence of rings indicative of Po precursors (^{238}U, ^{234}U, ^{230}Th, ^{226}Ra, and ^{222}Rn) and the presence of high ^{206}Pb/^{207}Pb ratios are interpreted to mean that isolated Po halos could only have been created from concentrations of Po atoms that were isolated from precursors and encapsulated within biotite and fluorite crystals (presumably by the Creator). A separate progenerative uranium source would, thus, be precluded and unavailable for emplacement of the Po ... or so Gentry thinks.



^{238}U DECAY SERIES			^{235}U DECAY SERIES			^{232}TH DECAY SERIES		
Symbol	Particle Emitted	Half-life Period	Symbol	Particle Emitted	Half-life Period	Symbol	Particle Emitted	Half-life Period
^{238}U	a	4,51 x 10^9 yrs.	^{235}U	a	7.13 x 10^8 yrs	^{232}Th	a	1.39 x 10^{10} yrs.
^{234}Th	ß	24.1 days	^{231}Th	ß	25.6 yrs.	^{228}Ra	ß	6.7 yrs.
^{234}Pa	ß	1.14 minutes	^{231}Pa	a	3.43 x 10^3 yrs.	^{228}Ac	ß	6.13 hours
^{234}U	a	2.35 x 10^5 yrs.	227Ac	ß	2.2 x 10^1 yrs.	^{228}Th	a	1.90 yrs.
^{230}Th	a	8 x 10^4 yrs.	^{227}Th	a	18.6 days	^{224}Ra	a	3.64days
^{226}Ra	a	1.62 x 10^3 yrs.	^{223}Fr	ß	22 minutes	220Rn	a	54.5 seconds
^{222}Rn	a	3.82 days	^{223}Ra	a	11.2 days	^{216}Po	a	0.158 seconds
^{218}Po	a	3.05 minutes	^{219}At	ß	0.9 minutes	^{212}Pb	ß	10.6 hours
^{214}Pb	ß	26.8 minutes	^{219}Rn	a	3.92 seconds	^{212}Bi	ß	60.5 minutes
^{214}Bi	ß	19.7 minutes	^{215}Bi	ß	8 minutes	^{212}Po	a	.3 x 10^{-7} sec
^{214}Po	a	1.5 x 10^{-4} sec	^{215}Po	ß	1.83 x 10^{-3} sec	^{208}Pb	-	stable
210 Po	ß	22years	^{215}At	a	10^{-4} seconds			
^{210}Bi	ß	5 days	^{211}Pb	ß	36.1 minutes			
^{210}Pb	a	140 days	^{211}Bi	ß	2.16 minutes			
^{206}Pb	-	stable	^{211}Po	a	0.52 seconds			
			^{207}Pb	-	stable			

IV-8
TABLE SHOWING THE DECAY CONSTANTS FOR THE RADIOACTIVE ELEMENTS

NOTE: *The text is correct*, but a reader on Octber 17, 2000, has called my attention to an error in the table. The data for ^{238}U DECAY SERIES shows ^{210}Po, beta, 22 years. This should read: ^{210}Pb, beta, 22 years. And ^{210}Pb, alpha, 140 days. This should read: ^{210}Po, alpha, 140 day.

From this base, Gentry drew the conclusion that Po halos in biotite and fluorite must indicate nearly instantaneous, "fiat" creation of granite during Genesis Week (Gardner 1989).

Numerous attempts have been made to counteract Gentry's claim and to show that Po halos are formed by less dramatic processes. None of these has been fully satisfactory.

Attempts to explain Gentry's conundrum include the following:

(A) The halos were created by hydrothermal fluids that carried or injected the polonium into the crystals (Joly 1917; Kerr-Lawson 1927; Henderson 1939; Henderson & Sparks 1939; York 1979; Chaudhuri & Iyer 1980).

(B) The halos were formed from Po ions in fluids that were released during the weathering of uranium-bearing minerals (Meier & Hecker 1976).

(C) The large numbers of ^{210}Po halos can be explained by diffusion of beta-emitting Pb isotopes (Hashemi-Nezhad et al. 1979).

(D) The halos were not really formed by disintegration of polonium but are merely variants of uranium halos (Moazed et al. 1973).

Gentry has met the counter claims with additional arguments, pointing out that:

(A) There is no evidence for hydrothermal fluid injection, which might bring radioactive precursors into position to create the isolated Po halos, since the mineral samples containing Po halos are from fresh, unweathered rock.

(B) Distribution of the beta-particle-emitting lead isotopes is inadequate to explain the presence of short-lived ^{218}Po and ^{214}Po nuclei.

(C) No remnants of uranium or other precursors occur in the biotite and fluorite crystal nuclei to support the contention that the Po halos are variants of uranium halos.

Gentry, therefore, continues to challenge the geologic community to prove that the Earth is older than 6,000 years (Feather, 1978; Gentry, 1983, 1988).

New Evidence Against Gentry's Hypothesis

Richard Wakefield (1987-88, 1988) demonstrated that some rocks near Bancroft, Ontario, Canada, which contain Po halos in biotite, are uranium-rich, calcite-biotite veins associated with granite pegmatites. Careful documentation of the geological relationships shows that these veins and pegmatites must have been introduced in Precambrian time, long after the primordial origin of the regional terrane. Such an age spread is, of course, incompatible with Gentry's interpreted time scale.

Wakefield's study, however, did not satisfy Gentry, who [illogically] disregards the time relationships implicit in the crosscutting of veins and dikes and the sequences of events in their metamorphism (Gentry 1983, 1988, p. 325-327). Moreover, in Gentry's hypothesis creation of metasediments, metavolcanic rocks, and metamorphosed intrusive gneiss complexes are all permitted from Day 1 to Day 3 of the Genesis Week. His model makes any Po-halo-bearing granite or pegmatite primordial, regardless of any complex history of the terranes in which they are found.

Therefore, although the ancient age of the Po-bearing rocks may be resolved for geologists, Gentry remains unconvinced and persists with his argument: *if the minerals that give the Po halos crystallized in granites and pegmatites from melts after millions of years of cooling history, the lives of the various isotopes are insufficient for them to have survived. Gentry's hypothesis, by this reasoning, must be correct.*

He wants the geologic community to produce evidence that shows how Po halos in granite can form by natural instead of supernatural processes. No one has done this up to now.

Odd Circumstantial Facts

When I looked closely into Gentry's Po halo studies, I noted four odd circumstantial facts contrary to his hypothesis. The first oddity is that his *Po halos all occurred in granites and granite pegmatites, never in any other rock types, excepting locally near Bancroft.*

In that area, the uranium-bearing calcite veins cross-cut the granitic rocks, and Po halos are absent from mafic rocks whether the mafic rocks are older or younger in age than the granites. This is true even when biotite is relatively abundant among the mafic minerals. These Po-halo-free rocks include biotite-bearing gabbros, diorites, and tonalites, as well as their volcanic equivalents. On the basis of field, chemical, and microscopic textural relationships, all of these mafic rocks are crystallized from magmas at high temperatures.

It is odd that Po halos are found only in certain, supposedly primordial, biotite-bearing granites and not in all primordial, biotite-bearing rocks. The Creator was evidently very selective about where he tucked the short-lived Po!

A second oddity I discovered was that *all of the granites in which Gentry found Po halos also contain myrmekite*. Myrmekite is a replacement mineral intergrowth, a fact that suggests that Po halos may not be present in all granites but only in granites formed by replacement processes. Conversely, perhaps only granites containing myrmekite should exhibit Po halos. In reality these do not always contain Po halos. Again, the Creator was very selective.

Some granites are derived from melted sedimentary or rhyolitic volcanic rocks, some by fractionation within magma (either partial melting or fractional crystallization), and some by partial melting and rising of magma that leaves behind a mafic residue (restite). Granites derived from melts do not contain Po halos.

The third oddity I noted is that *Po-halo-bearing rocks are always associated with uranium concentrations*. Gentry describes several uranium-rich localities that contain Po halos, including some in Finland, Sweden, Germany, Canada, and New England (Gentry 1988, page 36; Wiman 1930).

Why, one must wonder, would an all-powerful Creator choose to put Po halos only in rocks that contain abundant uranium? If Gentry is correct, and Po halos have no association with uranium, why does the Creator not put the Po halos also in granites free of uranium concentrations?

Polonium, being one of the daughter products of the radioactive decay of uranium, is expected to be found near uranium concentrations. To suppose a supernatural origin for the Po-halo-bearing granites is irrational.

A fourth oddity became apparent to me later as I delved into the detail of Gentry's hypothesis. *Only selected Po halos, those for the isotopes* ^{218}*Po,* ^{214}*Po, and* ^{210}*Po (products derived in* ^{238}*U disintegration) have been found by Gentry (Dutch 1983; Gentry 1983). Potential Po isotopes of other mass numbers (*^{215}*Po,* ^{211}*Po,* ^{216}*Po, and* ^{212}*Po) are produced in the* ^{235}*U and* ^{232}*Th disintegration series (Fig. IV-8), but Po halos of these types are not found.*

Why might the Creator not make Po halos of these other types, since all are available in nature? Does this unusual omission imply some simple natural cause for the selective presence of certain Po halos?

The True Origin of Polonium Halos

Biotite and coexisting myrmekite are both formed during replacement processes in granite. It follows that Po halos in biotite that coexists with myrmekite must also be attributed to replacement processes.

The properties of radon are germane to this understanding. Radon (^{222}Rn) is the radioactive decay product of ^{226}Ra which evolves into ^{218}Po. As an inert gas, it (^{222}Rn) moves freely through cracks in rocks unimpeded by reactions with minerals lining the cracks. Evidence for this ease of radon travel is noticeable in water wells prior to earthquakes. The creeping rock movements associated with seismically-active terranes open avenues for radon-bearing water to move into lower-pressure pore space and to the surface. Therefore, on the basis of this mobility, we would expect radon to move into a shattered and sheared habitat of diorite or gabbro that was in the process of being converted to myrmekite-bearing granite.

As ^{222}Rn is the precursor for ^{218}Po, this polonium isotope is the first one to be formed in the decay process. Although the half life of ^{218}Po is relatively short (3.05 minutes), enormous numbers of ^{222}Rn concentrate as a dissolved element along with silica in hydrous fluids, which then migrate in response to tectonic pressures into porous sites in the mafic crustal rocks.

Two factors favor diorite or gabbro sites for the formation of Po halos in conjunction with myrmekite-bearing granite and pegmatite development.

(1) Biotite (a common mineral in some diorite or gabbro) is cleavable easily on the planar "leaves" of biotite "books." These cleavage surfaces constitute porosity into which hydrous fluids carrying radon gas can move.

(2) In both biotite and fluorite the crystal lattices contain sites whose negatively charged fluoride ions (F) or hydroxyl ions (OH^{-1}) can be accommodated. These lattice sites are relatively large, and provide space where similar-sized ions can enter and take up lattice positions.

When atoms of ^{222}Rn decay to form in succession ^{218}Po, ^{214}Po, and ^{210}Po, the three polonium isotopes exist as negatively charged ions, Po^{-2}, whose sizes are similar to the fluoride and hydroxyl ions. In this way polonium isotopes are naturally accommodated and concentrated into fluorite (CAF_2) and biotite in granitic rock that is subjected to shear stress.

Thus, polonium was deposited in new crystals that grew from voluminous hydrothermal flushing of sheared and fractured, formerly-solid, mafic rock. Quartz and exotic minerals replaced mafic minerals, creating granite and pegmatite in their place. Two receptive mineral structures, (1) biotite cleavability (giving permeability to radon-carrying fluids) and (2) open-lattices in both biotite and fluorite crystals, explain why those minerals become repositories for polonium, and why the tracery of Po halos prove its ephemeral presence. The large volumes of hydrothermal fluids involved in this process are compatible with rapid growth of large pegmatite crystals of fluorite, biotite, and other minerals.

In the wall rocks near such shattered zones, where small primary crystals may be disseminated in the original diorite or gabbro, the stresses can shear them, and thus allow introduced fluids to aid recrystallization, by the annealing of microfractures, and secondary growth that enlarges the crystals. Since the large "books" of biotite in pegmatite and the small crystals of biotite in adjacent granite both develop through replacement processes at temperatures below the mineral melting intervals, these biotites and fluorites, whether growing or recrystallizing, provide ready-made lattice sites for rapid precipitation of polonium ions. Simultaneous growth of this kind of biotite and fluorite along with movement of dissolved ^{222}Rn atoms into the crystals enables rapid accumulation of Po isotopes. These concentrations then decay to produce the Po halos.

The volumes of radon that emerge from deep in the Earth's crust, dissolved in hydrous emanations, can be tremendous where uranium is abundant. Concentrations of this ambient radon can provide the enormous numbers of atoms needed to produce the Po decay halos. Radon emanating from a uranium source is a continuous chain of disintegration episodes that can provide a constant supply of new gas to a diorite or gabbro body as it is transformed into granite or pegmatite.

From these insights it follows that Po halos in a granite need not have been produced in a short time. Some halos may have formed early, some later. Rapid entry of radon and precipitation of polonium could occur if a gabbro or diorite site were made porous and depressurized by tectonism.

The frequent coexistence of Po halos in biotite with myrmekite in plagioclase and microcline of the same rock fabric gives a clear indication that a progressive replacement process in solid, unmelted rock has taken place. No magma is involved in this process.

Finally, the presence of ^{218}Po, ^{214}Po, and ^{210}Po halos only in granites and pegmatites and the absence of ^{216}Po, ^{212}Po, ^{212}Po, and ^{211}Po halos in these same rocks become understandable. Three rationales attest to this logic.

First, the half lives of radon isotopes for the different Po isotope precursors are diagnostically different. For ^{222}Rn in the ^{238}U series [the source for the observed Po halos], the half life is 3.82 days. By contrast, for ^{219}Rn in the ^{235}U series, the half life is 3.92 seconds, and for ^{220}Rn in the ^{232}Th series, the half life is 54.5 seconds. *The ^{222}Rn has about 84,000 or 6,000 times as much time to enter the biotite as does ^{219}Rn or ^{220}Rn!*

Second, the ^{216}Po, ^{215}Po, ^{212}Po, and ^{211}Po daughter isotopes have half lives that are measured in fractions of seconds rather than the 140 days for ^{210}Po and 3.05 minutes for ^{218}Po. *The ^{210}Po has over three million times the longevity of the sister series equivalents!*

Third, the relative abundance of released ^{222}Rn gas is proportionately much greater in most terranes than the abundances of released ^{219}Rn and ^{220}Rn gas.

Therefore, the combination of extremely short half lives of ^{219}Rn and ^{220}Rn gas [and their daughter polonium isotopes] and the relatively small quantities generated make the formation of ^{216}Po, ^{215}Po, ^{212}Po, and ^{211}Po halos impossible. These isotopes of radon and polonium, which could produce the missing Po halos, convert to Pb isotopes so quickly that their radon gas can never travel far from its source before decaying. Polonium from these isotopes can never migrate to and accumulate in distant biotite and fluorite in sufficient quantities to produce any halos.

The Buckhorn Pegmatite, A Test Case

Let us try these deductions on a suitable terrane. In 1988 Richard Wakefield and I examined several uranium-bearing and Po-halo-bearing pegmatites in an area of coexisting myrmekite in pegmatites, gneiss, and granite. The latter lithologies comprise the wall rocks adjacent to the pegmatites.

One particular pegmatite that we studied is the Buckhorn pegmatite that occurs along Highway 36, 19 km southwest of Bancroft, Ontario. Thick quartz vermicules characterize the myrmekite in this body, suggesting that both the pegmatite and granite result from replacement of an older hornblende-biotite diorite or gabbro gneiss at temperatures below the melting interval of granite. The myrmekite in wall rock and pegmatite is similar, with medium to coarse quartz vermicules (Haynes 1986).

These vermicules in myrmekite-bearing granite and Buckhorn pegmatite are diagnostic of a non-magmatic origin by replacement of diorite and gabbro rather than from magma. The compositional relationships depend on the calcium content of the plagioclase in the original rock from which the granite and pegmatite were derived.

Island remnants of diorite and gabbro occur in the granite to attest to this history, and they support the hypothesis that the precursor rocks were diorite or gabbro. Examples of these islands remnants can be observed in road cuts at the intersection of Highways 36 and 507; and their wide distribution supports the hypothesis that replacement occurred on a pluton-wide scale.

Geologic Setting of the Buckhorn Pegmatite

The uranium- and thorium-bearing Buckhorn pegmatite is a terrane of hornblende-plagioclase (diorite) gneiss, quartzo-feldspathic (diorite) gneiss, and pink, coarse-grained, massive, biotite granite. The hornblende-plagioclase gneiss in the wall rock of the pegmatite consists dominantly of polygonal hornblende, biotite, and normally zoned plagioclase. Quartz, microcline, magnetite-ilmenite, sphene, and calcite are minor constituents. The microcline fills interstices and locally encloses the other minerals. The quartzo-feldspathic gneiss is similar but contains less biotite and hornblende and more quartz and feldspar.

The pegmatite consists of coarse crystals of pink, perthitic microcline, biotite, albite, and quartz. Broken fragments of plagioclase are commonly surrounded by microcline. Myrmekite with relatively coarse vermicules occurs occasionally along the borders of the large pink microcline crystals. Albite lamellae in the perthitic microcline are not uniformly distributed as in granites that have crystallized from a melt, but are irregularly scattered through the crystals. Much of the albite in the microcline occurs as veins, which in some places have the same optical orientation as the plagioclase in the adjacent myrmekite. Some veins also contain quartz blebs or vermicules. Po halos occur sparsely in large biotite books, two to four cm in diameter (Fig. 2, Fig. 3, and Fig. 4).

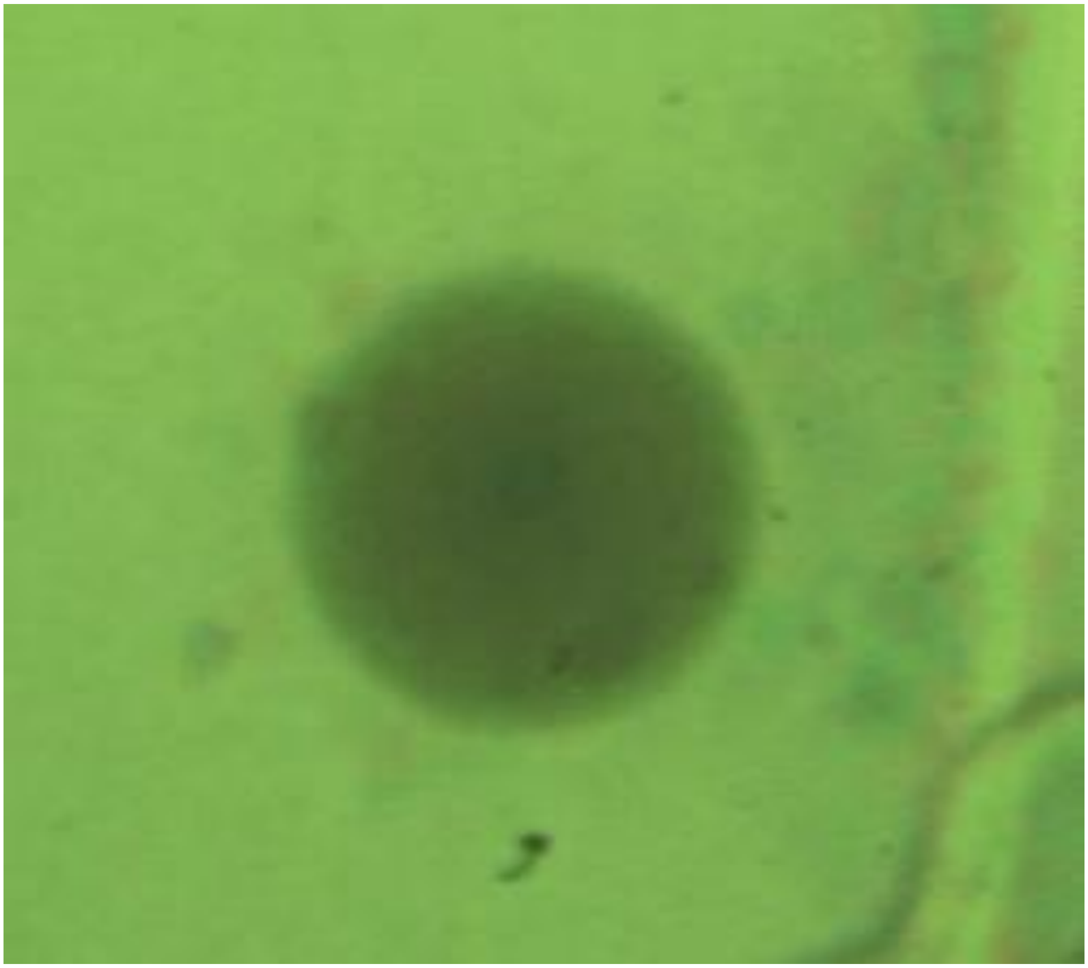


Fig. 2. Photo of ^{210}Po halo in biotite from the Buckhorn pegmatite.

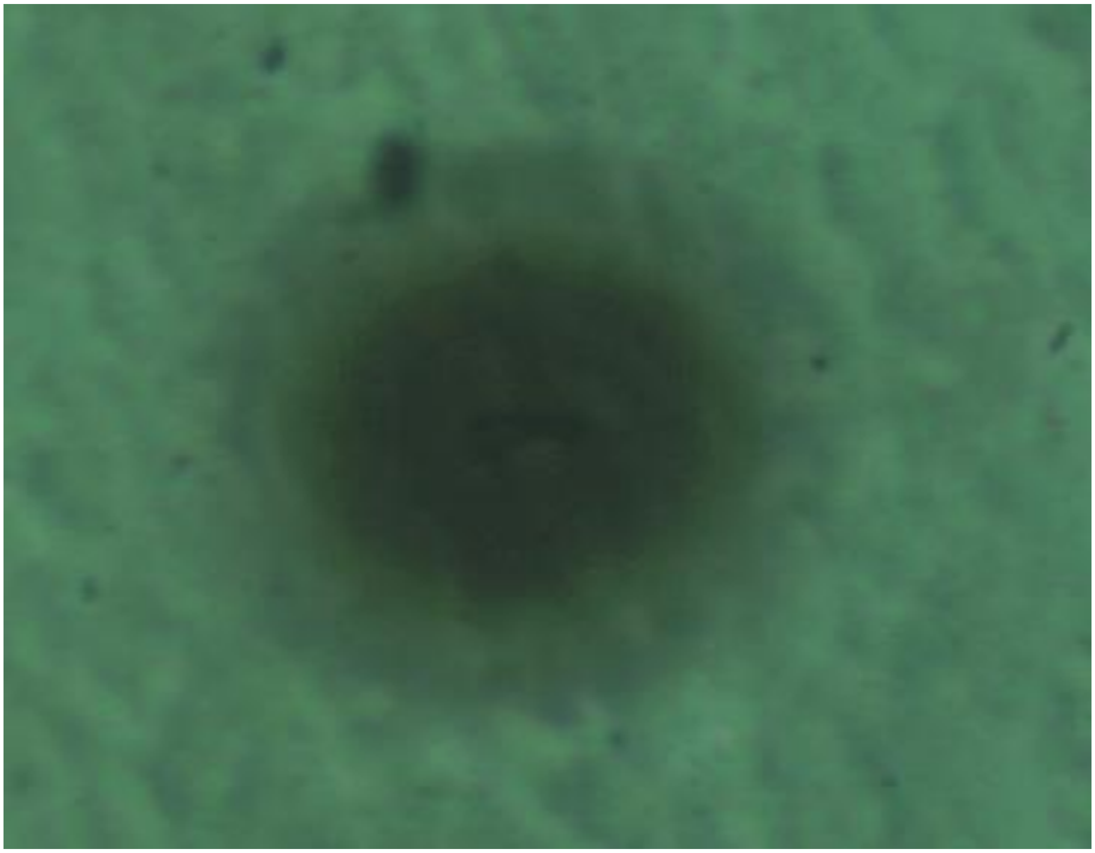


Fig. 3. Photo of ^{214}Po halo in biotite from the Buckhorn pegmatite.

Fig. 4. Photo of a fracture in biotite in which migrating ^{210}Po and/or ^{210}Pb ions have created damage to the biotite lattice parallel to the fracture. This negates the hypothesis by Gentry that such damage along veins do not exist. Nevertheless, isolated halos are common and do not show connection to veins. (Image scale is different from image scale in Figs. 2 and 3.)

In the quartzo-feldspathic gneisses adjacent to the Buckhorn pegmatite, microcline, albite, quartz, and biotite are the dominant minerals; hornblende is generally absent and presumably has been replaced by quartz. Magnetite, calcite, and sphene are common accessories. Rounded sphene granules are the same dimensions as in the adjacent hornblende gneiss. Myrmekite with medium to coarse quartz vermicules borders the microcline grains. Chlorite containing iron oxide dust is a common alteration product of the biotite. Some biotite crystals have ragged edges and quartz sieve textures. Zircons with halos are rare. Po halos are absent.

Generally, in diorite or gabbro that contains hornblende and pyroxene, the composition of the plagioclase tends to be calcic but not as calcic as in diorite or gabbro in which biotite is the sole ferromagnesian silicate. Hornblende and pyroxene incorporate calcium into their lattice structures. Thus, when these minerals are abundant, less calcium is available to go into plagioclase. In contrast, because biotite does not accommodate calcium in its lattice structure, most of the available calcium in that kind of diorite or gabbro goes into the plagioclase. This high-calcium plagioclase has the effect, when biotite gabbro is replaced by granite, of producing quartz vermicules in associated myrmekite that are coarser than where hornblende of pyroxene gabbro is replaced by granite.

Regionally, granite in and near the Buckhorn pegmatite contains myrmekite with quartz vermicules. This suggests that the granite adjacent to the Buckhorn pegmatite was originally a biotite gabbro or calcic diorite.

Uranium Mines of the Bancroft District, Ontario

Three uranium mines [Silver Crater, Fission, and Faraday] are situated in the same terrane as the Buckhorn pegmatite (Hewitt 1957; Bedell 1982, 1985). Local Po halos are found in biotite (Figs. 2, 3, and 4) and fluorite in these mines. Several rock types including gabbro, diorite, monzodiorite, monzonite, and syenite comprise the country rock in the region surrounding these mines, all of them essentially free of myrmekite. Beyond the Bancroft area in the Anstruther area, however, granite is present instead of syenite, and it exhibits myrmekite with coarse quartz vermicules.

The absence of myrmekite in the region where syenite occurs has a logical explanation as excessively sodic replacement. Cataclastically sheared diorite and gabbro bodies are replaced by fluids carrying Na^{+1}, K^{+1}, and Ca^{+2} (Lumbers, personal communication, 1987). These ions have converted the diorite and gabbro to monzodiorite, monzonite, and syenite, but only locally into granite.

In the former diorite and gabbro, relatively calcic plagioclase crystals have become sodic (albite to oligoclase) instead of being relatively calcic (andesine and labradorite). In these modified rocks calcite is found filling the interstices between broken silicate grains or concentrated in veins. K-feldspar locally is introduced, but the coexisting plagioclase is so sodic in syenite and/or granite that myrmekite is not formed (Collins 1988). Precursor hornblende and pyroxenes in the diorite and gabbro bodies have also recrystallized (as biotite and/or sodic amphiboles).

The fluids that created this regional evolution from mafic to siliceous rock also brought in uranium, which became concentrated in localized sites. The biotite and fluorite in the uranium ores in the three mines contain Po halos formed essentially at the time the diorite and gabbro were recrystallized and replaced [as monzodiorite, syenite, and granite].

It should be noted, however, that not all biotite "books" and samples of fluorite in the pegmatites and calcite veins in these modified rocks contain uranium halos or Po halos. The local absence of the Po halos suggests that only in certain places were concentrations of radon sufficient to produce visible Po halos.

Polonium Halos Explained

The formation of granite by replacement of solid rocks means that Gentry's theory is no longer tenable. He can no longer legitimately say that Po-halo-bearing granites must form by supernatural means.

Solid diorite and gabbro rock, which had previously crystallized from magma, has been subjected to repeated cataclasis and recrystallization. This has happened without melting; and the cataclasis provided openings for the introduction of uranium-bearing fluids and for the modification of these rocks to granite by silication and cation deletion.

In uranium ore-fields the extra uranium provides an abundant source of inert radon gas; and it is this gas that diffuses in ambient fluids so that incipient biotite and fluorite crystallization is exposed to it. Radon (^{222}Rn) decays and Po isotopes nucleate in the rapidly growing biotite (and fluorite) crystals whence they are positioned to produce the Po halos.

The whole process of Po halo formation can be accomplished without calling on a Creator to do it. The serendipity that has emerged from these observations implies that Po halos in myrmekite-bearing granite indicate a non-magmatic origin for the granite. The argument comes full circle when it meets Gentry's initial [truthfully made] observation that magmatically-derived granites cannot contain Po halos: the half-lives of the Po isotopes are simply too short.

The above material was taken from pages 128-140 in Hunt et al. (1992), except for the illustrations. Fig. 1 comes from Collins (1988.) The other figures are supplementary illustrations. See http://www.polarpublishing.com for publishing company information.

Collins (1988) "Hydrothermal Differentiation" can be ordered from Theophrastus Publications S.A., 33 J. Theologou Str., Zographou, Athens 622, Greece: $47.00 (U.S.).

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