MYSTERY OF THE RADIOHALOS

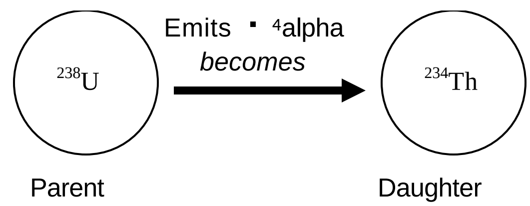
- Current physical laws may not have governed the past.
- Earth's primordial crustal rocks, rather than cooling and solidifying over millions or billions of years, crystallized almost instantaneously.
- Some geological formations thought to be one hundred million years old are in reality only several thousand years old.

Grant these propositions and—any researcher will tell you— the entire structure of the historical natural sciences would dissolve into formlessness. Few certainties would remain. Yet these very possibilities (and others equally disintegrative) have been suggested in a remarkable series of papers published over the past several years in the world's foremost scientific *Journals—Nature, Science,* and *Annual Review of Nuclear Science,* among others. Nor has this assault upon orthodoxy elicited a vigorous counterattack: the research results published to date have been so cautiously and capably elaborated, and evidence so thoroughly piled upon evidence, as to forestall any outcry by those whose scientific sensibility may have been outraged. While some investigators appear finally to be arming themselves for combat, the issue has not yet been joined.

It was over a decade ago that Robert V. Gentry, puzzling over questions about the Earth's age, directed his attention to an obscure and neglected class of minute discolorations in certain minerals. He has since examined more than 100,000 of these "radiohalos," and without doubt stands as the world's leading authority on the subject. As an assistant professor of physics at Columbia Union College (Takoma Park, Maryland), he has brought to bear upon the halos an array of sophisticated instrumentation such as few researchers ever have the privilege to wield. As a result, he has converted the entire field of radiohalo research into an exact science, transmuting the microscopic spheres of mystery into rich mines of exciting and challenging information.

RADIOACTIVE HALO (or RADIOHALO): "In some thin samples of certain minerals, notably mica, there can be observed tiny aureoles of discoloration which, on microscopic examination, prove to be concentric dark and light circles with diameters between about 10 and 40μm lone micrometer is one-millionth of a meter] and centered on a tiny inclusion. The origin of these halos (first reported between 1880 and 1890) was a mystery until the discovery of radioactivity and its powers of coloration; in 1907 Joly and Mugge independently suggested that the central inclusion was radioactive and that the alpha-emissions from it produced the concentric shells of coloration.. . halos command attention because they are an integral record of radioactive decay in minerals that constitute the most ancient rocks" (1).

Glossary of Technical Terms



A parent radioactive atom decays into a daughter atom in various ways, one of which is by the emission of an alpha particle from the parent atom's nucleus. Numerous types of radioactive atoms occur in nature, but only three are the initiators of a decay series: uranium-238 (^{238}U); uranium-235 (^{235}U); and thorium-232 (^{232}Th).

(The numerical superscript signifies how heavy the element is. Isotopes of the same element have different weights but nearly identical chemical behavior—as for example (^{238}U) and (^{235}U). An alpha particle has a weight of 4.)

Each of the three decay-series initiators decays, by a chain of steps, into lead. For example, the alpha-decay steps in the ^{238}U series are the following (steps not involving alpha-decay are not shown here):

$^{238}U \rightarrow {}^{234}Th$	$^{232}Rn \rightarrow {}^{218}Po$
$^{234}U \rightarrow {}^{230}Th$	$^{218}Po \rightarrow {}^{214}Pb$
$^{230}Th \rightarrow {}^{226}Ra$	$^{214}Po \rightarrow {}^{210}Pb$
$^{226}Ra \rightarrow {}^{222}Rn$	$^{210}Po \rightarrow {}^{206}Pb$

Similarly, ^{235}U decays by a different series of steps to ^{207}Pb, and ^{232}Th decays to ^{208}Pb. Note that while all the series end up with lead, each one results in a different isotope of lead.

The half-life of a given type of radioactive atom is the time during which half the atoms in any collection will decay. The half-life of ^{238}U is 4½ billion years. Half-life, decay rate, and decay Constant are closely related quantities. If we assume that the decay rate has not changed over geologic time*, and if we measure 1) how much of a parent in a rock has decayed into its daughter; and 2) the current rate of this decay, then we can, it is generally believed, assess the date when the parent was incorporated into the rock— that is, the date when the rock was formed. In the case of Earth's oldest rocks, this date (some 3½ billion years ago) is thought to be the time when the molten Earth first cooled down sufficiently for rocks to solidify from the primordial magma.

*Numerous other assumptions and technicalities also come into play.

**This review is based upon a series of telephone interviews with Robert V. Gentry, as well as the available technical literature.*

Gentry's studies have led him to the following conclusions:

1) Some halos ("polonium" halos) imply a nearly instantaneous crystallization of Earth's primordial rocks: and this crystallization must have occurred simultaneously with the synthesis/creation of certain elements.

2) Some halos correspond to types of radioactivity are unknown today.

3) Whereas radiohalos have been thought to afford the strongest evidence for unchanging radioactive decay rates throughout geological time (and these rates enable scientists to determine rock ages), in actuality the overall evidence from halos requires us to question the entire radioactive dating procedure: something appears to have disrupted the radioactive clocks in the past.

4) Halos in coal-bearing formations that arc conventionally thought to be 100 to 200 million years old suggest these strata to be only several thousand years old. Further, the time required for coal formation is much less than previously thought.

5) Taken together, these conclusions point to one or more great "singularities" in Earth's past—events or processes that are discontinuous with the rest of history, unique occurrences that critically affect the data we now have. If we attempt to interpret these data solely in terms of current processes, we go astray.

In this report we will discuss only those researches leading to conclusion (1), reserving the rest for a subsequent report.

January 29, 1975

You ask for my opinion of Dr. Robert Gentry's work on pleochroic polonium halos. I spent a number of hours reviewing this fascinating work with him some weeks ago. I was impressed with the clarity of the evidence for "anomalous halos"—that is, cases where there are rings indicating the presence of some *members of the normal radioactive decay chain without the* other *members of the family tree that normally* are *present, that normally do show up in rings of their own, and that* have *to be there on present views of the radioactive decay chains involved. If the evidence is impressive, the explanation for it is far from clear. I would look in normal geologic process of transfer of materials by heating and cooling; in isomeric nuclear transitions; and in every other standard physical phenomenon before I would even venture to consider cosmological explanations, let alone radical cosmological explanations. To explore all the avenues that need exploring would take months, not the few hours I was privileged to spend in Dr. Gentry's company. A few days ago I reviewed this work, all too briefly, with Dr. G. Wasserburg of Cal Tech, who is an expert in the radioactive dating of rocks, whose opinion would be much -more to the point than mine, especially if he will give it to you in writing.**

JOHN A. WHEELER
(Professor of Physics,
Princeton University)

*Professor Wheeler requested that his letter be printed in full. Dr. Wasserburg's views have not been obtained.

THE CONSERVATISM OF SCIENCE

Many have noted a conservatism in science essential to its orderly advance: skepticism toward radically new ideas enables scientific journals to retain focus, prevents anarchic descent into theoretical chaos, and makes it possible to extend currently reigning theories as far as they can bear before replacing them with other theories yet more embracive. A successfully modified, "tested" theory is preferable to a new "untried" theory. And so scientific knowledge advances in an orderly fashion, with as few wrong turns as possible.*

Gentry has so far avoided clashing with this conservatism, chiefly by concentrating his efforts on publication of data rather than discussion of their implications—and also by the good fortune that his work has been slow to draw widespread attention. That is beginning to change, however. But perhaps the reaction of a number of prominent physicists to Gentry's work on polonium halos (see insets on this and the following page) is the most significant gauge of what will be forthcoming. This reaction is noteworthy both for the confidence expressed in Gentry's work and for the almost uniformly conservative— albeit open—stance toward any extrapolations from the raw data that challenge accepted theory. Of those whose opinions we sampled, only one seemed to suggest (without wishing to be quoted) that we not publicize Gentry's work. He felt that the subject should be "left to the experts," while cautioning that it is too early to reject the conventional view of Earth's history.

In the end, it is, presumably, the evidence which will decide the issue. Let us look more closely at the radiohalos themselves.

**This conservatism—and its deceptive advantages—will receive continuing discussion in these newsletters.*

THE NATURE OF HALOS

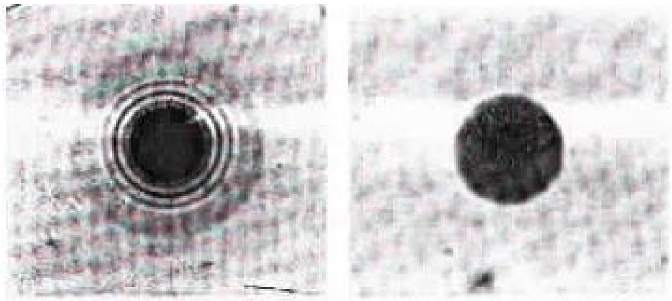
If a small grain (inclusion) containing radioactive atoms is embedded in certain rock minerals, the alpha particles emitted front the radioactive atoms travel outward from the inclusion and damage the crystalline structure of the mineral, in time producing the visible discoloration typifying halos. Since each type of radioactive atom emits alpha particles with a characteristic energy, and since this energy determines how far the particle will travel in the host mineral, the diameter of a halo's rings guides researchers in determining which radioactive element is responsible for the halo. If the radioactive element in an inclusion is the initiator of a decay series, then a group of concentric halo rings results, each ring corresponding to a step in the decay series, that is, to alpha particles of a particular energy. In the case of the ^{238}U series, with eight alpha-decay steps, there are five distinct halo rings (some of the alpha particles are so close together in energy that their rings are not distinguishable).

The conventional argument drawn from observed radiohalo sizes is summarized by Struve:

"There is excellent evidence that the rates of radioactive processes measured in the laboratory at the present time are valid also for the remote past. If a radioactive element and its decay products are embedded in a crystal, each alpha particle emitted during disintegration travels a certain distance that depends only on the rate of that particular decay step. The more rapid this rate, the greater the energy of the alpha particles, and the farther they go before being stopped and producing a color change in the crystal.

"Suppose a speck of ^{238}U has remained undisturbed since the formation of a mineral containing it. Then, because the rate of disintegration at each successive emission is different, eight concentric rings of mineral discoloration will be found surrounding the particle of uranium. These rings. . . have been found in many rocks of different geological ages, and the diameters of the respective rings are always the same.

"Thus it can be concluded that the rates of disintegration of uranium and thorium are constant" (2).



A uranium-238 halo (left) and a polonium-210 halo in biotite. Scale is 1 cm equivalent to 45 µm.

As we will learn in a subsequent review, the evidence from halos has led Gentry in a direction quite opposite from Struve's. But more than that, Gentry's halo research appears to strike at the roots of virtually all contemporary cosmologies, posing a fundamental problem which has so far resisted every effort to solve it in conventional terms. This is the problem of the polonium halos.

Comments by Leading Scientists

Before the demise of the journal, Pensée, *the editor—in preparation for a planned article on Gentry's work— approached a number of leading scientists for their assessment of polonium halos. The following responses were received during the first month or so of 1975.*

PROFESSOR TRUMAN P. KOHMAN, Department of Chemistry, Carnegie-Mellon University, Pittsburgh. "I do not believe that 'Gentry's contentions' can be regarded as of 'rather startling nature.' However, some of his experimental findings (like those of his predecessors) are quite difficult to understand, and the ultimate explanations could be interesting and even surprising. Many persons probably do not take them seriously, believing either that there is something wrong with the reported findings or that the explanations are to be found in simple phenomena which have been overlooked or discarded. . . . I believe it can be said that Gentry is honest and sincere, and that his scientific work is good and correctly reported. It would be very hard to believe that all, or any, of it could have been fabricated

PROFESSOR EDWARD ANDERS, Enrico Fermi Institute, University of Chicago. "His [Gentry's] conclusions are startling and shake the very foundations of radiochemistry and geochemistry. Yet he has been so meticulous in his experimental work, and so restrained in his interpretations, that most people take his work seriously. . . I think most people believe, as I do, that some unspectacular explanation will eventually be found for the anomalous halos and that orthodoxy will turn out to be right after all. Meanwhile, Gentry should be encouraged to keep rattling this skeleton in our closet for all it is worth."

PROFESSOR EUGENE P. WIGNER, Department of Physics, Rockefeller University, New York. "Even though I know Dr. Gentry personally, I am not sufficiently familiar with his scientific results to be able to judge them. Personally, however, I have a very high regard for him."

DR. EMILIO SEGRE, Istituto Di Fisica "Guglielmo Marconi," University Degli Studi, Rome. "The photos [of radiohalos] are re-markable, but their interpretation is still uncertain."

PROFESSOR FREEMAN DYSON, Institute for Advanced Study, Princeton. "Supposing that the results of Gentry are confirmed, what will it mean for theory? I do not think it will mean any radical changes in geology or cosmology. It is much snore likely that the explanation will be some tricky point in nuclear physics or nuclear chemistry that the experts have overlooked. That is of course only my personal opinion and I am accustomed to being proved wrong by events. (I just lost a $10 bet that Nixon would be in office till the end of 1974. 1 will be glad to lose this one too.)"

DR. PAUL RAMDOHR, Emeritus Professor of Mineralogy, Heidelberg University, Heidelberg. "The very careful and timetaking examinations of Dr. Gentry are indeed very interesting and extremely difficult to explain. But I think there is no need to doubt 'currently accepted cosmological models of Earth formation'. Anyhow, there is a very interesting and essential question and you could discuss it, perhaps with cautious restrictions against so weighty statements like the one above in quotes. It would be interesting and good if more scientists would have more knowledge of the problems."

ACADEMICIAN G. N. FLEROV, Joint Institute for Nuclear Research, Moscow. "We made sure that [Gentry] carried out his investigations very thoroughly. . . - Therefore his data deserve serious attention. - . . It is not excluded that [polonium halos] have been formed as a result of the extremely rare combination of geochemical, geological and other conditions, and their existence does not contradict the logically grounded system of concepts involved in the history of Earth formation."

DR. E. H. TAYLOR, Chemistry Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee. "1 can attest to the thorouglsness, care and effort which Gentry puts into his work. In a general way these puzzling pieces of information might result front unsuspected species or phenomena in nuclear physics, from unusual geological or geochemical processes, or even from cosmological phenomena. Or they (or one of them) might arise from some unsuspected, trivial and uninteresting cause. All that one can say is that they do present a puzzle (or several puzzles) and that there is some reasonable probability that the answer will be scientifically interesting."

POLONIUM HALOS

The last three alpha decay steps in the uranium-238 decay series (see glossary above) involve the successive decay of polonium-218 (^{218}Po), polonium-2l4 (^{214}Po), and polonium-210 (^{210}Po). In contrast to the decay of the parent uranium, these steps occur very quickly; the half-lives of the three forms of polonium are 3.05 minutes, 164 microseconds, and 140 days, respectively. Polonium, therefore, is not thought to be observed in nature except as a daughter product of uranium and thorium decay.

That is where the enigma begins. For Gentry has analyzed numerous polonium halos possessing, in some cases, the rings for all three polonium isotopes; in other cases the rings for ^{214}Po and ^{210}Po; and in other cases, the ring for 2l0 alone– *but none of these halos exhibits rings for the earlier uranium-238 daughters.* These halos are evidence for parentless polonium, not derived from uranium.*

But the question then arises, How did the polonium inclusions ever become embedded in the host rocks (more specifically, in Earth's oldest—Precambrian—rocks)? On the conventional view, these rocks slowly cooled and crystallized out of the primordial magma (molten rock) over millions of years. Under such circumstances, any polonium (with its extremely short half life) that was incorporated into the solidifying rocks would have completely decayed long before the crystalline rock structure was established. No halos could have formed, for they consist precisely of radiation damage to this crystalline structure. Polonium rings should exist only *in conjunction with* the other uranium series rings. But since the actual halos were caused by parentless polonium, they require nearly instantaneous crystallization of the rocks, simultaneously with the synthesis or creation of the polonium atoms.

Gentry, well aware that this conclusion is unthinkable to most, has buttressed it with impressive experimentation:
fission track and neutron flux techniques (3) reveal no uranium in the inclusions that could have given rise to the polonium—a conclusion more recently confirmed by electron microscope x-ray fluorescence spectra (4); fossil alpha recoil analysis (3) demonstrates that neither polonium nor other daughter products migrated from neighboring uranium sources in the rock, which agrees with calculations based on diffusion rates *(5);* ion microprobe mass spectrometry yields extra-ordinarily high ^{206}Pb/^{207}Pb isotope ratios that are wholly inconsistent with normal decay niodes (6), but which are exactly what one would expect as a result of polonium decay in the absence of uranium.

To date there has been only one effort (7) to dispute Gentry's *identification* of polonium halos. As it turned out (4), that effort might better never have been written, the authors having been impelled more by the worry that polonium halos "would cause apparently insuperable geological problems," than by a thorough grasp of the evidences. Challenges to Gentry's *interpretation* of the polonium halos have been more noteworthy. English physicist J. H. Fremlin wrote in *Nature* (November 20, 1975) that "The nuclear geophysical enigma of the ^{310}Po halos is quite fascinating, but the explanation put forward . . is not easy either to understand or to believe." Fremlin proposed two possible explanations:

Geologic transfer. If there are uranium inclusions reasonably close to polonium halos, then it is possible that one or more of the uranium daughter products migrated from the uranium site to a new location, where subsequent decay gave rise to the polonium halo. Since the daughter products have much shorter half-lives than uranium, we would not expect to find any quantity of them remaining at the site of the halo. The polonium would therefore appear to be "parentless." The difficulty with this view is that transfer of uranium daughters in minerals occurs so slowly that the daughters would decay long before they could migrate any significant distance (3, 5).

If the sophisticated experimentation cited above proved telling against the transfer hypothesis, Gentry and several co-workers delivered a yet more conclusive blow in a very recent paper: polonium halos derived by geologic transfer from uranium sources have now actually been found in coalified wood deposits (8). Their presence here was to be expected: prior to coalification the wood was in a gel-like condition permeated by a uranium-bearing solution. Such a material "would exhibit a much higher transport rate as well as unusual geochemical conditions which might favor the accumulation of ^{210}Po"—quite different from the situation in mineral rocks. Further, of these uranium-derived polonium halos, none were found due to ^{218}Po, and only three could conceivably (but doubtfully) be attributed to ^{214}Po, in contrast to numerous ^{210}Po halos. The half-life of ^{210}Po we will recall, is 140 days, whereas the half-life of those forms of polonium which failed to generate halos in the coalified wood is a few minutes or less. So even under the ideal conditions in this wood, the short-half-lived ^{218}Po and ^{214}Po were not able to migrate rapidly enough from the parent uranium to form "parentless" halos. Clearly, then, such migration could not account for the ^{218}Po and ^{214}Po halos Gentry has found in Precambrian minerals, where the diffusion rate is very much lower even than in wood (5).

Isomer precursors. Two atoms with identical nuclear composition but different radioactive behavior are termed "isomers." For example, ^{212}Po (in the thorium decay series) decays to ^{208}Pb by emission of an alpha particle with an energy of 8.78 MeV, However, about one out of every 5500 ^{212}Po atoms emits an alpha particle with a much higher energy of 10.55 MeV. These rarely occurring, higher-energy ^{212}Po atoms are isomers, and they are apparently explained by sonic variation in nuclear structure. The suggestion has been made, therefore, that polonium halos may result from the presence of heretofore unknown isomers which are long-lived and which decay* into polonium. These isomers ("precursors" of polonium) would circumvent the cosmological problem caused by the short-half-life polonium.
However, not only are such isomers unknown, but a careful search has revealed the presence of no elements which might qualify as the required isomers (4, 5). "Experimental results have ruled out the isomer hypothesis" (5). –

"SINGULARITIES"

And so we have Gentry's conclusion in his reply to Fremlin: "But if isomers and uranium-daughter diffusion do not produce polonium halos in rocks, we are left with the idea that polonium halos originate with primordial Po atoms just as U and Th halos originate

**Gentry has also found halos with rings from polonium -218, -214, or -210, combined with a ring from polonium -212 which is in the* thorium *decay series. This last form of polonium is also parentless— that is, there are no halo rings for thorium itself or its other daughters.*

with primordial ^{238}U and ^{232}Th atoms. . . Carried to its ultimate conclusion, this means that polonium halos, of which there are estimated to be 10^{15} [one million billion] in the Earth's basement granitic rocks, represent evidence of extinct natural radioactivity, and thus imply only a brief period between 'nucleosynthesis' [creation - of elements] and crystallization of the host rocks" *(5).* In plainer terms, these rocks must have formed almost instantaneously upon the synthesis of the elements comprising them.

Gentry believes the evidence points to one or more great "singularities" that have affected Earth in the past, representing physical processes which we do not now observe. If this is so, then attempts to define these processes in conventional terms will prove fruitless, and the span represented by geologic time is a wide open question. Further (as we will explore in a subsequent review), Gentry concludes that the most recent "singularity" may have occurred only several thousand years ago. And he finds compelling reasons to question the entire radioactive dating scheme which undergirds our concept of geological time.

Gentry realizes that he still must reckon with the conservatism of science. While his experimental work has been impressive, few would yet concede that it is impregnable, or that his explanations are the only possible ones. As Wheeler remarked:

> *"If the evidence [for the polonium halo] is impressive, the explanation for it is far from clear. I would look in normal geologic process of transfer of materials by heating and cooling; in isomeric nuclear transitions; and in every oilier standard physical phenomenon before I would even venture to consider cosmological explanations, let alone radical cosmological explanations."*

While the evidence does not seem to favor the specific mechanisms Wheeler suggested in early 1975, Gentry can be sure that, in pressing his own decidedly radical explanations, the sound and fury lie yet before him.

**by beta-emission*

REFERENCES

1. R. V. Gentry, *Annual Review of Nuclear Science* 23 (1973), p. 347.
2. O. Struve, *Sky and Telescope 18* (June, 1959), pp. 433-5.
3. R. V. Gentry, *Science 160* (June 14, 1968), pp. 1228-30.
4. R. V. Gentry, *Science 184* (April 5, 1914), pp. 62-66.
5. R. V. Gentry, *Nature 258* (November 20, 1975), pp. 269-70.
6. R. V. Gentry, 1.1). Hulett, S.S. Cristy, et al., *Nature* 252 (December 13, 1974), pp. 564-66.
7. C. Moazed, R.M. Spector, and R.F. Ward, *Science 180* (June 22, I 973), pp.. 1272-74.
8. R.V. Gentry, W.H. Christie, D.H. Smith, et at., *Science 194* (October 15, 1976), pp. 315-18.