GENERAL SCIENCE NOTES

HOW SOLID IS A RADIOISOTOPE AGE OF A ROCK?

By R. H. Brown, Geoscience Research Institute

The steady spontaneous transmutation of a radioactive isotope into a stable daughter isotope provides a means for determining the length of time the accumulation of daughter atoms has been maintained in association with its parent source — the radioisotope age of the mineral that contains the parent and daughter atoms. It is reasonable to expect that a radioisotope age for a mineral formation should specify the length of time that formation has been in existence, and also the minimum age of any fossils that may be associated with it. On this basis a quantitative geologic time scale has been developed (Harlan et al. 1964, 1971).

To be suitable for geologic time scale calibration a radioisotope age must meet three requirements: chemical isolation, stratigraphic control, and biological control. To meet the requirement of chemical isolation there must be no indication that either radioactive parent atoms or daughter type atoms have been transferred into or out of the mineral during the indicated time period. Diffusion due to heat, and solution or deposition due to contact with water can violate the chemical isolation requirement. Stratigraphic control requires that the mineral sample come from a clearly defined geologic formation which has an expected age range that is consistent with the radioisotope age of the sample. For example, a radioisotope age of either 100 million years (m.y.) or 3000 m.y. would not be accepted as the "true" real time age of a rock obtained from a geologic formation that is unquestioningly of Cambrian classification, regardless of how precise and accurate the isotope determinations may be. To be desirable as a calibration of the phanerozoic time scale, a radioisotope age should also meet standards of biological control, i.e., it should relate to a mineral sample that is associated with the proper index fossils for the age in question. While biological control and stratigraphic control are interrelated, applying each explicitly makes a more stringent requirement. The reader who is interested in the stance of the professional literature on these criteria should consult W. B. Harland et al. (1964), George V. Cohee et al. (1978), and Giles S. Odin (1982).

Lack of chemical isolation generally (but not always) has been expected to produce radioisotope ages that are most likely to be younger than the correct real time age, particularly when the daughter isotope is highly mobile, as is the case for the inert gas (argon) produced by the radioactive decay of potassium. Radioisotope ages that are younger than what would be expected on the basis of stratigraphic control and biological control are usually accounted for as evidence that chemical isolation has not been maintained.

Radioisotope ages that are older than allowable on the basis of stratigraphic or biological control are explained as due to retention of daughter isotopes from a state in which the mineral components existed previous to the association in which they are now found. Brooks et al. (1976) list 22 examples of rubidium-strontium (Rb-Sr) ages ranging from 70 million to 3300 m.y. which are stratigraphically constrained to represent volcanic activity within the last 65 m.y. (late Flood and/or post-Flood volcanic activity, according to conservative Biblical creationist interpretations of geology). Five continents are represented in this set of examples. Othman et al. (1984) have recently reported an extensive study of 32 typical worldwide granulite samples that have geologic age assignments ranging from 20 to 3100 m.y., yet have samarium-neodymium (Sm-Nd) radioisotope ages that in most cases are greater than the geologic ages and range from 851 to 3744 m.y. Rb-Sr ages for this sample set range from 596 to 3650 m.y. Allègre & Rousseau (1984) report Sm-Nd ages ranging from 1870 to 3780 m.y. for a set of seven Australian shale samples that have geologic age assignments ranging from 200 to greater than 3300 m.y.

In contrast with the earlier perception that potassium-argon (K-Ar) ages for glauconites are probably less than the formation age, it has now been established that K-Ar ages for a glauconite should be considered suspect as too old, due to possible incorporation of radiogenic argon along with potassium at the time of glauconite formation (Odin & Dodson 1982). Volcanics associated with organic material that can be dated by radioactive carbon generally have a K-Ar age much greater than that given by radiocarbon for the eruption (Stapor & Tanner 1973). A prime example is the 485,000 K-Ar age for volcanics from a Mt. Rangitoto eruption which destroyed trees less than 300 C-14 years old (McDougall et al. 1969).

The brief review reported in this article should make it apparent that while techniques for the determination of radioisotope age are precise and accurate, the interpretation of a radioisotope age in terms of real time is subjective and will reflect the biases of the interpreter. For illustration, consider the 12.3 to 519 m.y. K-Ar ages obtained for glauconitized coprolites from the Gulf of Guinea (see Odin & Dodson 1982, p 286). A 12.3 million year age for a mineral presumed to have formed 500 m.y. ago could be explained as the consequence of argon loss caused by heating in a recent portion of the presumed 500 m.y. existence of the specimen. The 12.3 m.y. age also could be explained on the basis of radiogenic argon incorporation together with potassium in a crystallization that occurred only 4000 years ago. And the 12.3 m.y. could be considered to be a "correct" indication of the time this glauconite has been in existence (Odin & Dodson only presume that these coprolites formed "less than 100,000 years ago"). Each of these interpretations is equally valid scientifically until measured against definitive evidence to the contrary. One's theoretical biases will determine what he allows as definitive evidence, and how he treats this evidence. Returning to the title for this review, it can be said that the real time interpretation of a radioisotope age for a rock is no more solid than the theoretical perspective of the interpreter.

REFERENCES

Allègre CJ, Rousseau D. 1984. The growth of the continent through geologic time studied by Nd isotope analysis of shales. Earth and Planetary Science Letters 67:19-34.

Brooks C, James DE, Hart SR. 1976. Ancient lithosphere: its role in young continental volcanism. Science 193:1086-1094.

Cohee GV, Glaessner MF, Hedberg H, editors. 1978. Contributions to the geologic time scale. American Association of Petroleum Geologists Studies in Geology No. 6.

Harland WB, Smith AG, Wilcock B, editors. 1964. The phanerozoic time-scale. Geological Society of London. See also the 1971 supplement, Harland WB, Francis EH, editors.

McDougall I, Pollach AA, Stipp JJ. 1969. Excess radiogenic argon in young subaerial basalts from Auckland volcanic field, New Zealand. Geochimica et Cosmochimica Acta 33:1485-1520.

Odin GS, editor. 1982. Numerical dating in stratigraphy (Part I and Part II). NY: John Wiley & Sons.

Odin GS, Dodson MH. 1982. Zero isotopic age of glauconites. In: Odin 1982, Part I, p 277-305.

Othman DB, Polvé M, Allègre CJ. 1984. Nd-Sr isotope composition of granulites and constraints on the evolution of the lower continental crust. Nature 307:510-515.

Stapor FW, Tanner WF. 1973. Errors in pre-Holocene carbon-14 scale. American Association of Petroleum Geologists Bulletin 57(9):1838.