<u>Lead Isotope Dates and the Age of the Earth</u>

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Dalrymple (1984, p. 101-102; 1991, chapter 7) strongly argues for a 4.5 billion year old Earth on the basis of lead (Pb) isotopes in meteorites, lunar samples and Earth rocks. Of course, young-Earth creationists (YECs) reject these results because Pb-isotope dating clearly refutes their antiquated biblical beliefs.

As quoted by YEC Woodmorappe (1999, p. 24), Dalrymple (1984, p. 101) admits that many terrestrial lead samples do not EXACTLY lie on a 4.55 billion year old meteorite isochron. However, Woodmorappe (1999, p. 24) fails to mention that these deviations are trivial (also see Figure 8 in Dalrymple, 1984, p. 102). Specifically, the uncertainty in the age of the Earth as derived from Pb isotope measurements is only about 2% (Dalrymple, 1984, p. 101).

When compared with meteorites, Earth rocks generally have much more complex histories, which may include weathering from oxygen and water, melting, metamorphism (heating without melting), faulting or other alteration events. To be exact, the Earth is so dynamic that few terrestrial samples older than 3.8 billion years have been found (for some details, see Dalrymple, 1991, chapter 4).

As explained by Dalrymple (1991, p. 117), nature cannot fractionate (that is, separate and concentrate) 204Pb, 206Pb, 207Pb, and other lead isotopes from each other. The atomic masses of the different Pb isotopes are too similar and their chemical properties are identical. Unless YECs want to invoke groundless miracles or other speculations, the only known way of varying the 206Pb/204Pb and 207Pb/204Pb ratios in different rocks and minerals is through the radiometric decay of uranium OVER TIME.

Dalrymple (1991, chapter 7) also summarizes in great detail the various efforts of different researchers to unravel the origin and histories of terrestrial leads. Now, some YECs have accused Dalrymple (1991) of 'painting too rosy a picture' of radiometric dating. However, Dalrymple (1991, chapter 7) discusses both the successes (e.g., Tera, 1981) and failures (e.g., the faulty assumptions in Ulrych, 1967) in interpreting the geochronology of terrestrial leads. Despite Woodmorappe's (1999) misunderstandings about the Precambrian history of the Earth and the functioning of geological processes, Pb-isotope dating of meteorites, lunar samples and terrestrial rocks, as well as the great complexity and destructive processes on the Earth's surface are entirely consistent with the Earth being 4.5 billion years old (Dalrymple, 1991, chapter 7). At the same time, these data utterly demolish young-Earth creationism.

In an attempt to refute Dalrymple's (1984) claims that terrestrial leads are close to the meteorite lead-isotope isochron, Woodmorappe (1999, p. 24) quotes the following statement from Harper and Jacobsen (1996, p. 1131-1132):

'It is widely believed that studies of lead isotopes in terrestrial samples provide a well-determined age of the Earth (for an excellent review, see Dalrymple, 1991). We show this to be incorrect, even though a roughly accurate answer is sometimes obtained, but is not necessarily related at all to the formation of the Earth. Other widely cited systems such as Rb-Sr, I-Xe, and Pu-Xe also do not date terrestrial accretion and/or core formation in any well-defined sense.'

However, what are Harper and Jacobsen (1996, p. 1131-1132) really saying in this quotation? Do they agree with Woodmorappe and claim that a 4.5 billion year old Earth is an utter fantasy or are they saying that the age requires better resolution? Also, why do Harper and Jacobsen (1996, p. 1132) endorse Dalrymple (1991)?

In reality, Harper and Jacobsen (1996, p. 1131) argue that a new 182Hf-182W method can provide better resolution for dating the formation process of the Earth than traditional lead-isotope methods:

'Here we present an overview and some experimental results for the newly-developed 182Hf-182W isotope system that, once fully calibrated, may be able to constrain the mean age of the Earth PRECISELY [my emphasis].'

Also, Harper and Jacobsen (1996, p. 1150) admit:

'Age of the Earth estimates based on Pb and Sr isotopes are not likely to provide reliable information on the terrestrial accretion interval.'

In other words, Harper and Jacobsen (1996, p. 1131) correctly argue that the Earth did not simply appear from nowhere 4.5 billion years ago, but that it formed in stages over 100,000 to 10 million years, and that Pb isotope dating cannot provide adequate details on this accretion period. Dalrymple (1991, p. 346-347) clearly agrees with this view, except that he thinks the Earth took 20 million years or so to accrete. Harper and Jacobsen (1996, p. 1131) further explain that because the Earth accreted or grew over 100,000 to 10 million years, its 'age' is not clear-cut:

'The term "age of the Earth" is often employed loosely and may refer to three different senses. First, it can be defined as the age of the solar system, specifically obtained as the time of formation of the oldest known accreted objects at 4566 +/- 2 Ma ...[reference omitted]. This can be justified because models of planetary accretion imply rapid initial material coagulation processes leading to runaway accretion of proto-planetary "embryo" nuclei on a timescale of only 0.1 Ma ... [reference omitted]. A second commonly used definition refers to the time of the "end" of the Earth's accretion, that is to say to some time at which the Earth had grown to very near its present mass. Here the answer depends on the exact definition of "very near", because the accretion process had a long tail and is technically still continuing today. [new paragraph] A third usage, the "mean age" represents the mass-average age of accretion.'

Like Harper and Jacobsen (1996), Dalrymple (1991, p. 346-347) is well aware that detailed interpretations of Pb-isotope dates are somewhat uncertain:

'As Tera [1981] observed, it is probably significant that ancient galenas from three continents seem to define a common source with a common age and lead composition, and also that the age obtained is similar to the age determined for meteorites. It is also satisfying that the model ages calculated for the galenas by the congruency result are within a few percent of the ages measured by other dating methods ...[reference to table omitted]. The precise nature of the event of 4.53-4.54 Ga [billion years ago] is not entirely clear, but it is Tera's opinion that the age represents the time of U-Pb fractionation in the primary materials from which the Earth was formed. If this fractionation occurred at the time the Earth accreted, then the age is the age of the Earth; if not, then it represents the age of the debris from which the Earth was formed. Alternatively, the fractionation might be the result of separation of the Earth's materials into core and mantle. Regardless of the precise interpretation, the

near equivalency of this "age of the Earth" and the ages of the primitive meteorites indicates that the condensation of solid matter from the Solar Nebula, the formation of the meteorites' parent bodies, and the formation of the Earth as a planet occurred within a period of only 20 Ma [million years] or so.'

Obviously, Woodmorappe (1999, p. 24) has misrepresented Harper and Jacobsen (1996, p. 1131-1132) when he claims that this paper indicates that 'any' agreement between Pb isochrons and the 4.5 billion year old age of the Earth is only 'coincidental.' Considering Harper and Jacobsen's comments about the strengths and great potential of the Hf-W method to provide better details on the early formation of the Earth, including core formation, and how short-lived radioisotopes, such as 129I, form in supernovae and quickly die during the long history of an ancient Universe, this article provides no comfort to YECs like Woodmorappe.

Woodmorappe (1999, p. 24) also quotes Gariepy and Dupre (1991, p. 216-217), which supposedly is critical of terrestrial leads supporting a 4.5 billion year old date for the Earth:

'It was then thought that the Pb ores in these large deposits were derived from the mantle and the lower crust and evolved in a closed system. However, most lead ores of the world are 'anomalous' in that they do not fit a single-stage growth curve... a single stage evolution since 4.5 Ga [billion years ago] is unlikely.'

Like Harper and Jacobsen (1996, p. 192), Gariepy and Dupre (1991) argue that Pb-isotope dating of terrestrial samples is not sensitive enough to derive details on the Earth's formation because most terrestrial leads have had long and complex histories (also see chapter 7 in Dalrymple, 1991, which discusses the meaning of single and multiple stage leads). Nevertheless, the 4.5 billion year old date is basically correct, as stated in Gariepy and Dupre (1991, p. 192):

'In 1956, using data gathered on meteorites and on modern sediments considered representative of the Earth, Patterson evaluated this age at 4.5 Ga [billion years old], A FIGURE THAT HAS LARGELY BEEN CONFIRMED SINCE THEN [my emphasis].'

Here are some other statements by Gariepy and Dupre (1991, p.191, 192), which hardly support Woodmorappe's (1999, p. 24) crusade:

'The variations in the abundance of lead isotopes provide a USEFUL method of constraining a range of geological problems because i) it provides age information arising from the radioactive decay of U, Th and their daughter products into stable Pb isotopes, and ii) it retains a time-integrated record of U/Pb and Th/U ratios of the reservoir in which the Pb had developed. These reservoirs vary in scale and may embody the mantle, the continental crust, an ore deposit, a basement complex, a lithostratigraphic unit or the atmosphere-hydrosphere system. Thus, a reservoir may be defined as any geochemical unit of the Earth exchanging matter and energy with its environment. In the context of this chapter, reservoirs are those parts of the Earth that operate as a [sic] sources of Pb and possess distinctive U/Pb or Th/Pb values. These ratios are fractionated significantly during partial melting, fractional crystallization, regional metamorphism and hydrothermal circulation. They are also affected in complex ways by weathering, biological activity and other low temperature processes occurring near the surface of the Earth. As a result, the isotopic abundances of Pb vary widely in nature, depending on the age and the geological history of a given reservoir. [new paragraph] In contrast to the isotopes of light elements, the isotopes of Pb are not fractionated from one another during physico-chemical processes such as dissolution, metal transportation and precipitation.' [my emphasis]

'The chapter does not propose a unified model of Earth's evolution integrating all available geochemical and geological information, but rather attempts to point out how Pb isotopes CAN BE USED to decode certain aspects of terrestrial evolution and constrain some key parameters.' [my emphasis]

Finally, in contrast to Woodmorappe and other YECs, Gariepy and Dupre (1991, p. 224) argue:

'Although this chapter is focused on Pb isotopes as tracers of crust-mantle evolution, it should be emphasized that the combined use of several isotopic tracers is an EVEN MORE POWERFUL tool without which some of the remaining uncertainties will not be resolved.' [my emphasis]

CONCLUSIONS

The uncertainties over the age of the Earth raised by Dalrymple (1991), Harper and Jacobsen (1996) and Gariepy and Dupre (1991) are actually trivial (typically, 4.52 to 4.56 billion years, Dalrymple, 1991, p. 356) and provide no comfort to YECs. Terrestrial leads are very close to the 4.55

billion year old meteorite-based isochron and, as Dalrymple (1984, p. 101) points out, leads in Moon rocks also lie very close to the line and indicate a 4.5 billion year old age for the Moon. Besides misrepresenting the contents of Harper and Jacobsen (1996), Dalrymple (1984, 1991) and Gariepy and Dupre (1991) on the age of the Earth, Woodmorappe (1999, p. 24) produces no scientific references to attack lead isotope studies that clearly support an ancient origin for meteorites and Moon rocks. The only references that Woodmorappe (1999, p. 24) provides to supposedly attack lead isotope dates from meteorites are Witter (1974) and Williams (1992, p. 2), who are YECs and not geochronologists.

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