Early Lunar Differentiation and the Earth-Moon Connection

MAUD BOYET[1,2] AND RICHARD CARLSON[2]

[1]Universite Jean Monnet, St. Etienne, France (maud.boyet@univ-st-etienne.fr)
[2]Carnegie Institution of Washington, Washington, DC, USA (rcarlson@ciw.edu)

Coupled ^{146}Sm-^{142}Nd ($T_{1/2}$=103 Myr) and ^{147}Sm-^{143}Nd ($T_{1/2}$=103 Gyr) systematics were analyzed on lunar samples that span the range of source compositions created in the early lunar differentiation event (ferroan anorthosites, high-Mg suite norite, KREEP, low- and high-Ti basalts). If fit with a single isochron, the data agree with previous suggestions of a ~200 Ma duration for lunar magma ocean (LMO) crystallization [1, 2], but with an initial ^{142}Nd/^{144}Nd 20 ppm higher than chondritic, essentially the same as measured for terrestrial rocks [3]. Excesses in initial ^{142}Nd (ε^{142}Nd = 0.27 to 0.38 relative to O-chondrites) in crustal rocks 60025 and 78236, coupled to positive initial ε^{143}Nd, measured in most of crustal samples, indicate that they derive from a source strongly depleted in light rare earth elements (^{147}Sm/^{144}Nd~0.23-0.24). The source reservoir for lunar crustal rocks thus would be even more depleted than the terrestrial early depleted reservoir (EDR) formed on Earth during the first tens of Ma of Solar System history (^{147}Sm/^{144}Nd = 0.209) [3]. This geochemical signature cannot be reconciled with the current lunar magma ocean (LMO) models that suggest that the crust formed after approximately 70% crystallization of an LMO that initially had chondritic relative REE abundances. Two alternatives exist: 1) The lunar crust formed by post-magma ocean remelting and diapirism of LREE-depleted cumulates from the lunar interior [see also 4]. A two-point isochron for the crustal rocks provides an age of 64 (+97, -58) Ma after the beginning of Solar System formation or 4.50 Ga. If the thick crust is a secondary product, there is no reason to invoke its insulating qualities for explaining a delay of the LMO crystallization. Fitting the Sm-Nd data for the different groups of lunar samples (crustal rocks, low-Ti and high-Ti basalts) independently allows rapid (~60-120 Ma) evolution of the LMO at the limit of lifetime of ^{182}Hf [5, 6]. 2) If all the lunar igneous rock groups are considered together and related to crystallization of a single LMO, then the Sm-Nd data suggest a prolonged (~200 Ma) LMO crystallization interval and a bulk LMO with LREE-depleted character in common with the EDR of the Earth. This strengthens the Earth-Moon connection by requiring formation of the Moon from an already differentiated Earth.

References

[1] Nyquist *et al*. 1995, *GCA* **59**, 2817;
[2] Rankenburg *et al*. 2006, *Science* **312**, 1369;
[3] Boyet and Carlson 2005, *Science* **309**, 576;
[4] Longhi 2002, JGR 108, NO. E8, 5083;
[5] Kleine *et al*. 2005, *Science* **310**, 1671;
[6] Touboul *et al*., 2007, *LPSC*, 2385.

Release of C-14 from a closed final repository for low-level radioactive waste to the biosphere

G. BRACKE AND W. MÜLLER

ISTec, Institute for Safety Technology GmbH, Schwertnergasse 1, 50667 Cologne, Germany (guido.bracke@istec.grs.de; wolfgang.mueller@istec.grs.de)

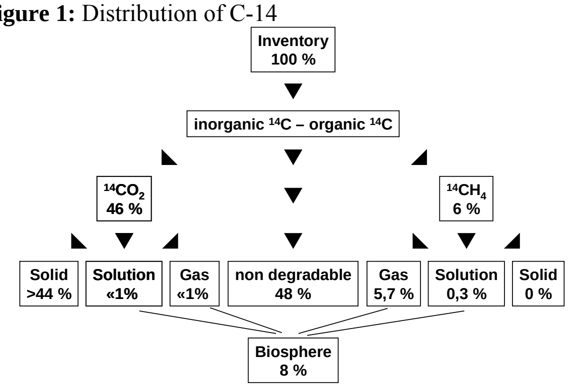
Introduction

The contribution of C-14 to radiation exposure in the biosphere from a repository for low-level radioactive waste can be significant. The pathways and processes of C-14 relevant to its release from a closed final repository for low-level radioactive waste are under investigation. Because a conservative approach may lead to undue overestimation of the potential radiation exposure, a more realistic approach is outlined.

Results

A more realistic approach includes:
- a reference scenario including technical measures
- the inventory of C-14 with speciation
- geochemical reactions in all compartments
- gas generation
- brine pathways
- gas pathways
- isotope exchange reactions
- sorption, precipitation
- exposure scenario

Figure 1: Distribution of C-14



Summary

At the present level of refinement, a more realistic assessment of the release of C-14 after closure of a final repository for low-level radioactive waste in a mine shows a significantly lower release of C-14 than previously used conservative approaches. This assessment predicts a significantly lower potential radiation exposure, thus increasing the safety margins to federal limits.

With this approach it is possible to demonstrate that a repository in a mine complies with the ALARA (as low as reasonably achievable) principle, thus facilitating licence approval. Conservative approaches are unable to demonstrate compliance other than with the limits for radiation exposure.