

High-resolution comparison of same-age interrupted sapropel sequences from four ODP sites

P. A. MEYERS AND M. ARNABOLDI

Marine Geology and Geochemistry Program, Department of Geological Sciences, The University of Michigan, Ann Arbor, Michigan, U.S.A. (pameyers@umich.edu)

Sapropel layers record periods of wetter-than-present Mediterranean paleoclimate that lasted 3-12 ky during precessional minima. Some sapropels are interrupted, which suggests that climate reverted to arid conditions like today for 200-1000 y before becoming wet again (de Rijk et al., 1999; Krishnamurthy et al., 2000; Mercone et al., 2001). We have studied an example of an interrupted sapropel layer – the sapropel deposited during insolation cycle 90 (955 ka) – at 1-cm intervals in four Ocean Drilling Program drill-holes to determine spatial differences and similarities in its expression. Hole 967A is located in the Levantine Basin and is influenced by monsoonal variations in Nile outflow. Hole 969D is on the Mediterranean Ridge and near the western limit of Nile influence. Hole 974C in the Tyrrhenian Basin is hydrologically isolated from most of the Mediterranean Sea and is instead sensitive to rivers draining the Apennines. Hole 975C is in the Balearic Basin, where it monitors runoff from the Pyrenees and the western Alps. The sapropel layer is similarly divided into two sublayers at the four locations – an upper layer in which organic carbon concentrations reach 4 to 6 wt%, and a lower layer in which they peak between 1 and 3 wt%. Concentrations differ between the sites because of differences in sedimentation rates of the mineral components that dilute organic matter. However, organic carbon mass accumulation rates are similar, which indicates similar paleoproductivity and preservation rates at the four locations. The mid-Pleistocene paleoclimate changes conducive to sapropel formation and interruption evidently were not only similar but also synchronous across the Mediterranean region.

References

- de Rijk S., Hayes A., and Rohling E., (1999). *Mar. Geol.*, **153**, 337-343.
 Krishnamurthy R.V., Meyers P.A., and Lovan N.A., (2000). *Geology* **28**, 263-266.
 Mercone D., Thompson J., Abu-Zied R.H., Croudace I.W., and Rohling E.J., (2001). *Mar. Geol.*, **177**, 25-44.

Lu-Hf constraints on early lunar differentiation

K. MEZGER, C. MÜNCKER AND E.E. SCHERER.

Institut für Mineralogie, Universität Münster, Corrensstr. 24, D-48149 Münster / Germany
 (klaush@nwz.uni-muenster.de)

The dominant chemical and mineralogical differentiation process on the Moon is most likely associated with the formation and subsequent crystallisation of a magma ocean. The major evidence for the existence of a magma ocean is the ancient anorthositic crust that once covered the lunar surface. The complementary heavier minerals that crystallised as cumulates from the magma must have included olivine, pyroxene, ilmenite and, if the ocean was deep enough, also garnet. Partial melts from these differentiated silicate and oxide layers gave rise to younger mare basalts that now cover parts of the Moon's surface. The exact nature of the lunar mantle is not known because it has not been sampled directly. However, radioactive parent-daughter systems such as ^{176}Lu - ^{177}Hf and ^{92}Nb - ^{92}Zr can provide important time constraints on these early differentiation processes, particularly if the two elements are sufficiently fractionated during magmatic processes. Therefore we obtained Lu-Hf and Nb-Zr isotope data for a variety of well dated lunar samples including one KREEP basalt, KREEP-rich highland breccias, low- and high-Ti mare basalts and lunar soils.

$^{92}\text{Zr}/^{90}\text{Zr}$ and $^{96}\text{Zr}/^{90}\text{Zr}$ in mare basalts agree with the chondritic value within the analytical errors of ± 0.5 and ± 1.5 ϵ -units (2σ), respectively. All analysed samples have $^{176}\text{Lu}/^{177}\text{Hf}$ ratios between 0.017 and 0.025, requiring substantial fractionation during melting by clinopyroxene or garnet. The initial ϵHf range from -1.9 in the KREEP rocks to $+16.6$ in high-Ti mare basalts. The initial $^{176}\text{Hf}/^{177}\text{Hf}$ values for mare basalts ($+7.3$ to $+16.6\epsilon$) are consistent with the data from Beard et al [1] using the revised ^{176}Lu decay constant [2] (0 to $+8$ ϵ) but expand the compositional range of mare basalts. Low- and high-Ti mare basalts overlap in their initial ϵHf . An initial ϵHf of $+3.3$ in one 4.3 Ga old KREEP-rich highland breccia and $+16.6$ in a ca. 3.7 Ga old Apollo-17 high-Ti mare basalt require a depleted source that has a time-integrated $^{176}\text{Lu}/^{177}\text{Hf} \geq 0.07$. Such high $^{176}\text{Lu}/^{177}\text{Hf}$ ratios require the accumulation of clinopyroxene and possibly garnet as the trace element controlling phases in the sources of mare basalts. The depletion curve defined by the highest ϵHf values indicates that the early differentiation on Moon must have been completed no later than 4.45 Ga ago. The absence of ^{92}Zr -isotope anomalies and the presence of small ^{182}W anomalies [3] confine the crystallisation age of the magma ocean to ca. 4.50 Ga.

References

- [1] Beard et al, (1998), *Geochim Cosmochim Acta*, **62**, 525-524; [2] Scherer et al, (2001), *Science*, **293**, 683-687; [3] Lee et al., (2001) *Meteoritics and Planetary Science* **36(9)**, A111