FURTHER Lu-Hf AND Sm-Nd ISOTOPIC DATA ON PLANETARY MATERIALS AND CONSEQUENCES FOR PLANETARY DIFFERENTIATION. J. Blichert-Toft , M. Boyet, and F. Albarède, Ecole Normale Supérieure de Lyon (46 allée d'Italie, 69364 Lyon cedex 7, France albarede@ens-lyon.fr).

Introduction: The coupled Lu-Hf and Sm-Nd isotope systematics on lunar basalts (Unruh et al., 1984 ; Beard et al., 1998), SNC meteorites (Blichert-Toft et al., 1999), and eucrites (Blichert-Toft et al., 2002) provide unique constraints on mineral segregation in the early magma oceans of various planets. The respective roles of the early crystallizing minerals olivine and clinopyroxene and the pressure-, and therefore gravity-dependent minerals plagioclase and garnet together with the fingerprinting of ilmenite crystallization, which requires extreme degrees of fractionation to reach saturation, are illuminated by the isotope geochemistry of Hf and Nd in planetary magmatic rocks. Here we present new ^{176}Lu-^{176}Hf and ^{147}Sm-^{143}Nd data on KREEP basalts, SNC meteorites, including two nakhlites and an orthopyroxenite, eucrites, and angrites.

Results: The KREEP basalt 15386.51 and the clast-poor impact melts 68415.72 and 14310.66 give slightly negative ε_{Hf} (-0.1 to -4.0) and ε_{Nd} (-3.0 to -4.0) at the time of their formation at ca. 3.8 Ga. These results are consistent with Mezger et al.'s (2002) preliminary results and confirm that the mantle source of KREEP basalts has lower-than-chondritic Lu/Hf and Sm/Nd ratios. With respect to a lunar magma ocean with nearly chondritic abundances of refractory elements,.this mantle source potentially complements that of the low-Ti and high-Ti basalts, which is characterized by higher-than-chondritic Lu/Hf and Sm/Nd ratios.

As for other long-lived isotope systems, the Lu-Hf and Sm-Nd data of Los Angeles confirm its enriched 'crustal' character, which is very similar to Zagami and Shergotty, but contrasts with the source of DaG-476 and SaU 005, which just like QUE 94201 both show a strong indication of long-term depletion. Such a depleted character, although to a lesser extent, is also found for the two nakhlites analyzed here, Nakhla end Lafayette. The sample with the most depleted source so far is the orthopyroxenite ALH 84001.

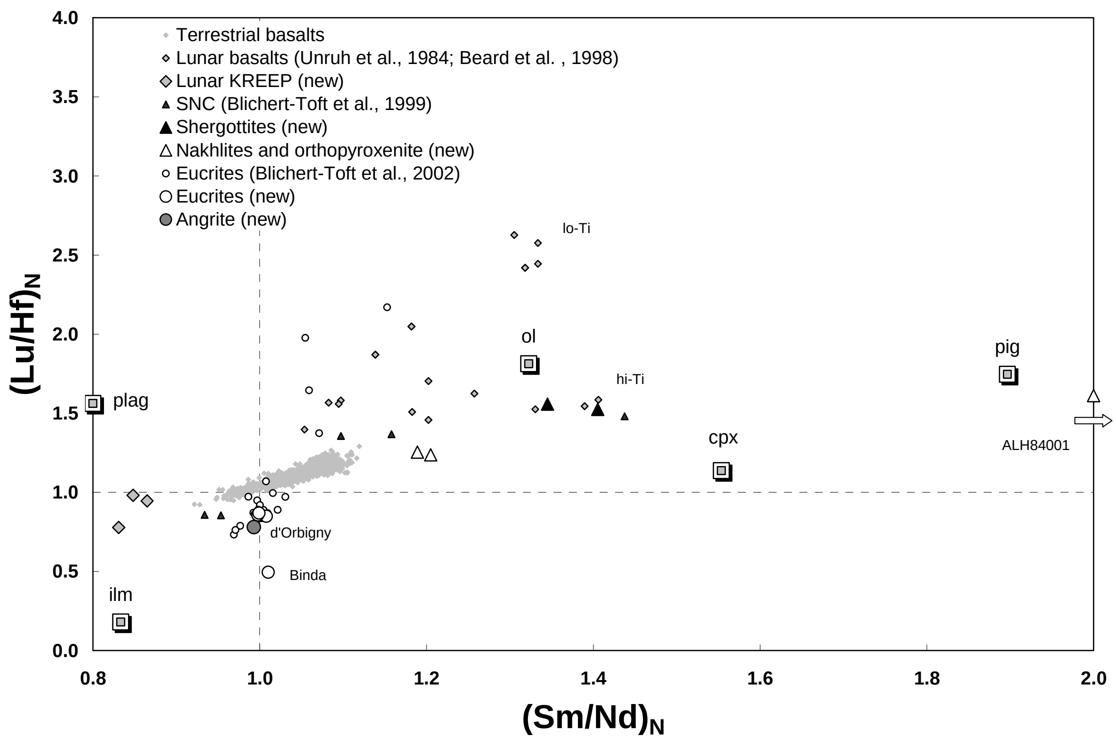

Figure 1: The chondrite-normalized Sm/Nd and Lu/Hf ratios of the mantle source of planetary magmatic rocks inferred from their Sm-Nd and Lu-Hf isotopic properties. These ratios are the parent/daughter ratios of the two Sm-Nd and Lu-Hf chronometric systems. The squares show the parent/daughter ratios of minerals in equilibrium with a chondritic melt and therefore help reconstruct the ratio of potential mantle sources evolving by crystallization of a magma ocean. The new samples are shown with respect to literature data. See Blichert-Toft et al. (2002) for the surces of terrestrial basalt and partition coefficient data.

Three new basaltic eucrites (Harayia, Nuevo Laredo, and Emmaville) fall within 0.5 ε units of the Sm-Nd isochron of Blichert-Toft et al. (2002), but Binda is clearly perturbed. For the Lu-Hf isochron, only Harayia slightly deviates from the previously determined isochron. These results do not modify the previous interpretation of the Sm-Nd and Lu-Hf eucrite isochrons (Blichert-Toft et al., 2002). The three angrites d'Orbigny, Sahara 99555, and Angra dos Reis fall on the eucrite Sm-Nd isochron. D'Orbigny falls on the Lu-Hf isochron, while the other two angrites are still awaiting chemical processing.

The Hf/Sm ratio of the KREEP and KREEP-like basalts is slightly higher that chondritic, which is also the case for the eucrite Harayia. Most of the new samples have near-chondritic ratios. The most conspicuous Hf/Sm ratio (1.5) so far is that of the eucrite Binda.

Discussion: As shown by Nyquist et al. (1992), the comparative Sm-Nd and Lu-Hf geochemistry of the Earth, the Moon, and Mars is best discussed in a diagram reporting the apparent parent/daughter ratios of the mantle sources of the magmatic rocks (Fig. 1). For eucrites (Vesta), we can only see magmatic products emplaced very shortly after the planet formed.

For the first time, we are clearly seeing the enriched complement to the highly depleted lunar mantle source of most lunar basalts. Since fractional crystallization is essentially incapable of fractionating incompatible elements in the residual liquids until the magma ocean has crystallized to a very large extent, most of the isotopic effects observed must reflect the re-melting of cumulates. The processes giving rise to the high-Ti lunar basalts, the depleted shergottites, and the nakhlites leave a rather similar Nd-Hf isotopic signature. The parent melts of these rocks probably represent the re-melting of deep pyroxene-olivine cumulates. In contrast, the parent magma of the KREEP basalts, and, possibly, of the enriched shergottites, may represent melts from a shallow source rich in plagioclase and ilmenite cumulates. This is in agreement with the high Hf/Sm ratio of these rocks, which for the KREEP basalts is to the high side of the chondritic value, and well above the chondritic values in shergottites (Blichert-Toft et al., 1999). The Nd and Hf isotopic compositions of angrites closely resemble those of basaltic eucrites. As shown by Blichert-Toft et al. (2002), the cumulate eucrites are best interpreted as plagioclase cumulates impregnated with highly differentiated liquids, probably melts from ilmenite-rich cumulates. The low-Ti lunar basalts are extracted from a source similar to cumulate eucrites.

None of these planetary processes seems to be mirrored by terrestrial basalts, for which the Hf-Nd isotopic variability is very small compared to that of extra-terrestrial magmas. The Hf-Nd isotopic variations of the terrestrial mantle are dwarfed by the extreme isotopic contrasts observed on the Moon, Vesta, and Mars. An important conclusion is that by 3.8 Ga, the mantle of these planets had not been efficiently stirred by convection.

References: [1] Beard et al. (1998) *GCA 62*, 525-544 [2] Blichert-Toft J. et al. (1999) *EPSL 173*, 25–39 [3] Blichert-Toft J. et al. (2002) *EPSL 204*, 167-181 [4] K. Mezger et al. (2002) *GCA 66*, A510 [5] Nyquist L.E. and Shih C.-Y. *GCA 56*, 2213-2234 [6] Unruh D.M. et al. (1984) *JGR 89*, B459-B477.