

## LUNAR Mg-RICH ROCKS AS ANALOGS OF TERRESTRIAL KOMATIITES: IMPLICATIONS OF EARLY OUTGASSING OF EARTH'S VOLATILE ELEMENTS

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Komatiites (ultramafic volcanic rocks) are common among Archean terrains, but rare or absent among rocks < 2.8 Ga old, which implies that the Archean upper mantle was fundamentally different from the modern one. The magma(s) parental to a certain group of lunar samples appear to have formed by exceptionally high-degree partial melting, like the magmas parental to komatiites: The Mg-rich suite of pristine nonmare rocks comprises numerous extremely magnesian troctolitic rocks, with Fo<sub>87</sub> olivine; a few even have Fo<sub>92</sub> olivine, i.e., as magnesian as liquidus olivine from a typical komatiite melt. One crucial difference between the ancient lunar mantle and the modern terrestrial one is that the latter is far richer in volatiles, most notably H<sub>2</sub>O.

Extraterrestrial samples indicate that the Earth formed hot, and volatiles were probably outgassed from its outer mantle. Isotopic data from Allegre *et al.* (1983) confirm that the MORB source region outgassed > 4.4 Ga ago, but parts of the mantle did not. Eventually, the outer mantle must have regained volatiles, either by admixture of a veneer of carbonaceous chondrite-like material, acquired during a 'late heavy bombardment' > 3.9 Ga ago, or else by slow outgassing from the deeper mantle. Traces of water lower the solidus temperature (T<sub>s</sub>) of mantle peridotite by hundreds of degrees. It is widely assumed that due to greater radiogenic heating, the Archean lithosphere was much thinner than the modern one. Actually, wherever the outer mantle remained dry, the lithosphere was probably thick. The lithosphere is rigid and cools by conduction, unlike the asthenosphere which cools by convection. Convection is inhibited by viscosity, which is proportional to exp(30\*T<sub>s</sub>/T). Without water to lower T<sub>s</sub>, the lithosphere/asthenosphere boundary must have been at a much higher T, which implies that it was deep. A locally dry lithosphere, comparable in thickness to the modern one, can explain many Archean phenomena. The exceptionally high liquidus temperatures of komatiites imply ascent of diapirs from great depth in a hot, rigid lithosphere: Melting seldom occurs in the asthenosphere, because convective cooling causes dT/dP to be quasiadiabatic, and thus dT<sub>s</sub>/dP > dT/dP. Ultramafic melts are also more likely to come from a deep, dry source region because it would retain more pyroxene and less olivine. Metamorphic mineral assemblages from some Archean terrains indicate that sialic crust survived burial to depths > 30 km. Without insulation by a thick lithosphere, sialic materials at these depths would have been extensively melted.

Allegre *et al.*, 1983. *Nature* **303**, 762-768.

## AN <sup>107</sup>Ag\* - <sup>108</sup>Pd INTERNAL ISOCHRON FOR GIBEON (IVA)

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Previous studies (Kelly and Wasserburg, 1979; Kaiser and Wasserburg, 1983) have established the presence of ratios of <sup>107</sup>Ag/<sup>109</sup>Ag which are far above the value for normal Ag. These effects were observed in IVB iron meteorites and some anomalous meteorites highly depleted in volatiles. A correlation of <sup>107</sup>Ag/<sup>109</sup>Ag with <sup>108</sup>Pd/<sup>109</sup>Ag was found, indicating that the excess of <sup>107</sup>Ag (<sup>107</sup>Ag\*) was correlated with Pd, implying the presence of <sup>107</sup>Pd in the meteorites. These workers were not able to establish an internal isochron. Chen and Wasserburg (1983) showed that <sup>107</sup>Ag\* was present in IIIAB iron meteorites, which are not greatly depleted in volatiles and showed internal isochrons using metal, phosphides and sulfide for Cape York and Grant. We have applied this approach to IVA meteorites which are depleted in volatiles. Samples of Gibeon metal and sulfide were analyzed and gave <sup>109</sup>Ag concentrations of ~ 6 × 10<sup>10</sup> atoms/g metal. The observed <sup>107</sup>Ag/<sup>109</sup>Ag value of Gibeon uncorrected for blank for metals #6 and #7 are 3.05 and 2.66, respectively. For Hill City, the measured <sup>107</sup>Ag/<sup>109</sup>Ag = 3.31. This silver is extremely radiogenic. The blank corrected data are presented in Table 1 and Figure 1. It can be seen that both Gibeon and Hill City lie above the correlation line through the origin found by Kaiser and Wasserburg (1983). The sulfide in Gibeon was analyzed by sequential leaching. The first leach labelled "EXT" for exterior and the residue of the leaching process labelled "INT" for interior. Both of these samples

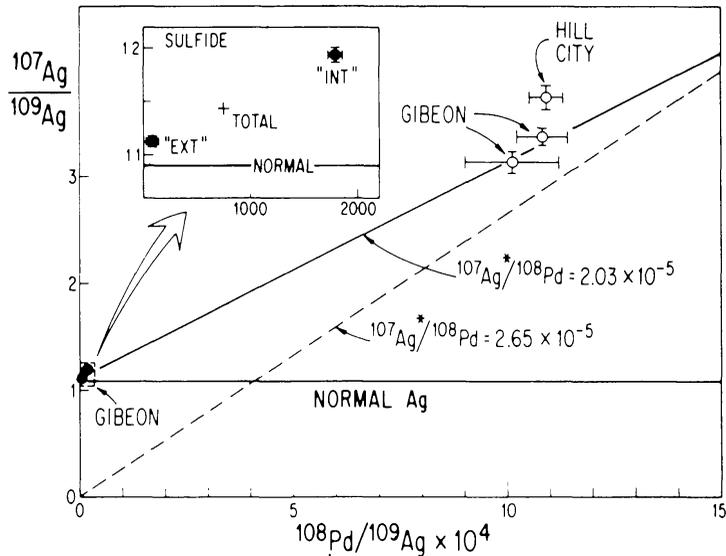


Fig. 1

show the presence of  $^{107}\text{Ag}^*$  with the interior sample yielding a 10% excess. The calculated value for the total sulfide (INT and EXT) is also shown in the figure. A line drawn through the metal (open circles) and sulfide (full circles) points gives an initial  $^{107}\text{Ag}/^{109}\text{Ag} = 1.11$  as compared with the normal value of  $1.0897 \pm 0.0018$ . It follows that there is a correlation of  $^{107}\text{Ag}^*$  with Pd within these "two phases" of Gibeon with an initial  $^{107}\text{Ag}/^{109}\text{Ag}$  that is about 2% enriched. The concentration of Pd in the "sulfide" of Gibeon is quite high. This is similar to results on Santa Clara "sulfide" (Kaiser and Wasserburg, 1983). Metallographic, SEM and EMP investigations showed both "sulfides" to be mixtures of metal, sulfide and phosphide produced by shock melting. The FeNi metal comprises between 30 to 50% weight of the "sulfide" inclusions. We conclude that Gibeon and Hill City show large excesses of  $^{107}\text{Ag}^*$ . The Gibeon data indicates an internal isochron with the initial  $^{107}\text{Ag}/^{109}\text{Ag}$  being  $\sim 2\%$  radiogenic due to the transport of  $^{107}\text{Ag}^*$  during the cooling history from the metal phase (after some  $^{107}\text{Pd}$  decay) to the sulfide which originally contained normal Ag. This locally unsupported  $^{107}\text{Ag}^*$  was then blended in the "sulfide" inclusion with surrounding metal due to shock melting. Some problems still exist with the detailed distribution within the "sulfide" possibly due to laboratory procedures.

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Table 1  
Ag and Pd in Gibeon (IVA) and Hill City (IVA)

Gibeon	$^{109}\text{Ag}$ analyzed ( $10^{11}$ atoms)	$^{107}\text{Ag}/^{109}\text{Ag}^a$	$^{108}\text{Pd}$ ( $10^{15}$ atoms/g)	$^{109}\text{Ag}^a$ ( $10^{10}$ atoms/g)	$^{107}\text{Ag}^{*b}$ ( $10^{11}$ atoms/g)
Metal #6	3.1	$3.37 \pm 0.02$	6.56	$6.1 \pm 0.3$	1.39
Metal #7	1.4	$3.13 \pm 0.02$	6.61	$6.6 \pm 0.7$	1.35
Sulfide INT <sup>c</sup>	6.3	$1.193 \pm 0.006$	2.27	127	1.31
Sulfide EXT <sup>c</sup>	5.5	$1.112 \pm 0.004$	0.406	505	1.13
Hill City	3.4	$3.74 \pm 0.02$	9.76	$9.0 \pm 0.3$	2.39

<sup>a</sup>Corrected for blank. <sup>b</sup>Calculated relative to normal Ag. <sup>c</sup>Bulk "sulfide" has  $^{107}\text{Ag}/^{109}\text{Ag} = 1.143$  and  $1.74 \times 10^{15}$   $^{108}\text{Pd}$  atoms/g.

Chen, J.H. and G.J. Wasserburg, 1983. *Geochim. Cosmochim. Acta*, in press.

Kaiser, T. and G.J. Wasserburg, 1983. *Geochim. Cosmochim. Acta* **47**, 43-58.

Kelly, W.R. and G.J. Wasserburg, 1979. *Geophys. Res. Lett.* **5**, 1279-1286.