^{187}Re-^{187}Os ISOTOPE DISTURBANCE IN LA PAZ MARE BASALT METEORITES.

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Introduction: Lunar mare basalt meteorites LAP02-205, -224, -226, -436, and LAP03-632 were discovered in the LaPaz icefield, Antarctica during the 2002/2003 ANSMET field season [1,2]. These basalts have been recognized as being paired on the basis of petrographic [1-3] and geochemical studies [3]. The LaPaz basalts, as well as offering a new suite of material in which to understand the origin and evolution of the lunar mare, also provide insight into the effects that impact and eventual arrival on Earth have on the isotopic and elemental composition of extraterrestrial materials. We present new Re-Os isotope data for the LaPaz mare basalts which indicates that both impact-induced shock and fusion melting during fall through the Earths' atmosphere may have affected the Re-Os isotope systematics of these meteorites. Despite these effects, the new data demonstrate the extremely low highly siderophile element (HSE) abundances in lunar mare basalts and indicate the importance of analysing unshocked lunar mare basalts to provide futher understanding of the HSE budget and Os isotope evolution of the lunar mantle.

Analytical Methods: 1.5 to 2g fragments of meteorite were crushed in an agate pestle and mortar under class 100 air flow. Powders were digested and equilibrated with spike for isotope-dilution analysis in reverse aqua regia at 220ºC. Separation/purification of Re and Os was accomplished via solvent extraction and microdistillation (Os) and anion-exchange chromatography (Re). Os isotope analysis was performed using negative thermal ionization mass spectrometry (Triton-TI), and Re analysis was performed using sector-field ICP-MS (Element 2). Blanks were highly consistent and low for both Re and Os. For example, duplicate measurements of blank Os concentrations yielded 0.37±0.05 pg/g with a ^{187}Os/^{188}Os composition of 0.1577±0.0011. The effect of chemical blank on individual results varied from negligible to significant (Table 1).

Results and Discussion: Blank corrected Re, Os and Os isotopic data for the LaPaz lunar mare basalts is presented in Table 1. Re and Os concentrations range between 0.3 to 77.9 ppt and 0.1 to 3.9 ppt respectively, whilst the ^{187}Os/^{188}Os isotopic compositions encompass a surprisingly large range from 0.1684 to 0.6508; all are more radiogenic than the well constrained blank contribution. The Re/Os* and Os* variations for the LaPaz basalts are more extreme, and lower than typical terrestrial magmas (Fig 1.), a result in agreement with previous studies [4,5], highlighting the extremely low HSE abundances in lunar magmas relative to terrestrial equivalents. None of the samples show evidence for 'exogenous' meteoritic components. Of the initial Os isotopic ratios calculated for these samples at 2.9Ga (their likely formation age [6]), all but one are less than the Solar System initial resulting in strongly negative γOs; evidence for a multi-stage and complex evolution for these meteorites.

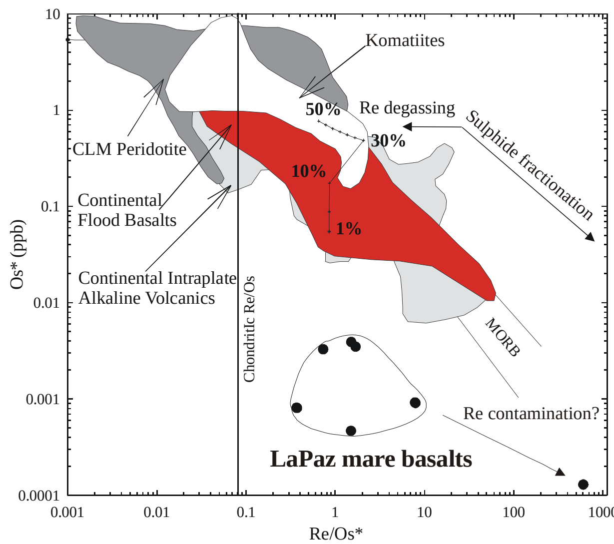

Fig. 1: Re/Os versus Os* for La Paz mare basalts versus terrestrial magmas and continental lithospheric mantle peridotites. Terrestrial partial melting model shown (in %).*

Two fragments of a LaPaz basalt, LAP02-224, were obtained for analysis, one from the centre of the meteorite (18) and the other from the outer fusion crust (17). The outer fusion crust portion exhibits the highest Re and lowest Os concentration, and the most radiogenic ^{187}Os/^{188}Os, of all the analyzed samples. This result is suprising given that Re would be expected to be volatile at fusion temperatures and in atmospheric conditions. A possible explanation for this might be contamination by Re-rich aerosols captured within the Antarctic ice. A two-point 'isochron' (Fig. 2a) gives an 'apparent age' for the LAP02-224 portions of 10.0±0.9Ma with a ^{187}Os/^{188}Os initial of 0.146±0.043; within error of the 2.9Ga corrected age initial for LAP02-432. This 'apparent age' is likely to represent a mixture of the age of the fusion event as well as the 'age' of the meteorite as total

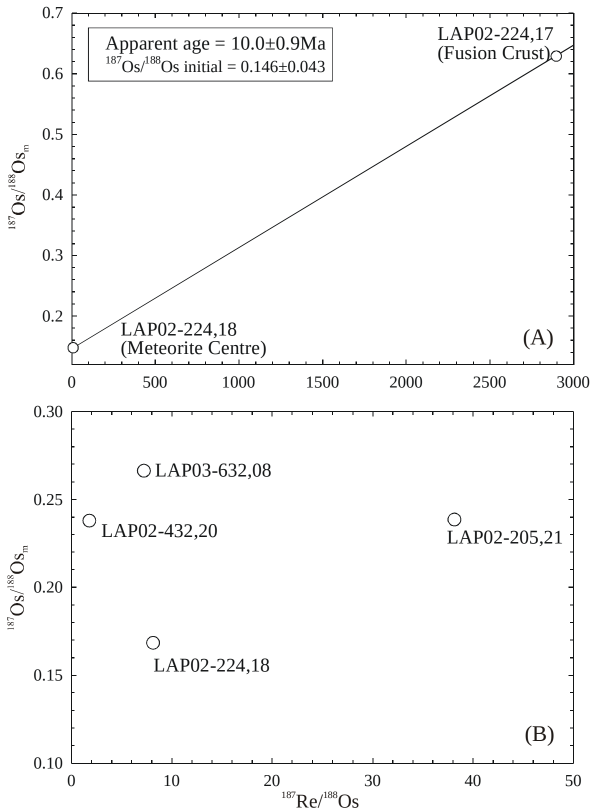

Fig. 2: $^{187}Re/^{188}Os$-$^{187}Os/^{188}Os$ for the La Paz mare basalt meteorites. (A) LAP02-224 fusion crust and centre, (B) Centres of LAP basalts (note differences in scale).

separation of fusion crust from unfused sample was not performed.

Apart from LAP02-224,17, all other samples were obtained from the centres of individual meteorites and so may offer an opportunity to look at isochronous relationships within this meteorite group. This is because the effect of 'nuggeting', where mineral-scale fractionation of Re from Os generates time-integrated variations in $^{187}Os/^{188}Os$, is likely to be a significant feature in rocks with very low HSE abundances. Unfused whole rock powder from the LaPaz basalts do not define any meaningful isochronous relations, but do show extreme, measurable variations in both the $^{187}Os/^{188}Os$ and $^{187}Re/^{188}Os$ (Fig. 2b, Table 1).

The extreme $^{187}Os/^{188}Os$ of the LaPaz basalts (the most extreme so far measured for lunar mare basalt samples), the non-isochronous relations and the highly variable and unrealistic γOs_i (Table 1) measured in these samples may reflect the influence of impact-induced shock processes on the Moon. All of the LaPaz mare basalt meteorites show evidence for shock metamorphism, with partially maskelynitised plagioclase, heavily fractured pyroxene, olivine and ilmenite, and significant melt vein networks present in all samples (1.3-2.1% of polished sections, [3]). Re has been shown in terrestrial environments to be volatile (e.g., [7]), and mobility of Re and Os has been documented in a number of terrestrial environments (Shirey and Walker [8], and references therin). The extreme temperatures and pressures of shock events may have a significant influence on the HSE budgets of some meteorites. If so, the non-systematic variation in $^{187}Re/^{188}Os$-$^{187}Os/^{188}Os$ space for these meteorites probably reflects amalgamations of the eruption ages of the basalts (~2.9Ga) and younger (<100Ma?) shock events, that took place on the Moon. The complex Re-Os systematics shown by these samples indicate that some caution may be required in the interpretation of other meteorite Re-Os analyses.

[1] Ansmet Newsletter (2003), 26 (2). [2] Ansmet Newsletter, (2004), 27 (1,3). [3] Day J.M.D. *et al.* (2005) *LPSC XXXVI*, this volume. [4] Birck J.-L. and Allègre C.J. (1994) *EPSL*, 124, 139-148. [5] Walker R.J. *et al.* (2004) *EPSL*, 224, 399-413. [6] Anand M.A. *et al.* (2005) *GCA*, submitted. [7] Sun W. *et al.* (2003) Nature, 422, 294-297. [8] Shirey S. and Walker R.J. (1998) Ann. Rev. Earth. Plan. Sci, 26, 423-500.

Table 1: Re-Os isotope results for LaPaz mare basalt meteorites. $2\sigma_m$ = measured error, $2\sigma_c$ = total calculated error

Sample	Weight (g)	Re (ppt)	% Re Blk	Os (ppt)	%Os Blk	$^{187}Re/^{188}Os$	$^{187}Os/^{188}Os_m$	$2\sigma_m$	$2\sigma_c$	$\gamma Os_{2.9Ga}$
LAP02-205,21	0.956	7.2	56	0.9	29	38.1	0.2385	7	67	Negative
LAP02-224,17	0.766	77.9	13	0.1	78	2900	0.6508	6	48	Negative
LAP02-224,18	0.767	5.9	66	3.9	11	7.3	0.1684	16	128	Negative
LAP02-226,13	0.803	2.4	82	3.7	11	3.5	-	-	-	-
LAP02-432,20	0.761	0.3	97	0.8	37	1.8	0.2379	6	25	+38.5
LAP03-632,08	0.775	0.7	94	0.5	50	7.2	0.2664	9	20	Negative