RE-EXAMINATION OF ^{26}Al-^{26}Mg SYSTEMATICS IN THE PIPLIA KALAN EUCRITE.

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Introduction: We reported at last year's LPSC [1] the preliminary results on the ^{26}Al-^{26}Mg and ^{53}Mn-^{53}Cr systems, in the Piplia Kalan eucrite, using thermal ionization mass spectrometry (TIMS). The purpose was to confirm and extend the important report by Srinivasan et al. [2, 3] who identified the presence of excess ^{26}Mg in plagioclase in this eucrite. This was the first report [2, 3] of clear excess of ^{26}Mg in a eucrite, after the extensive and pioneering search, 30 years ago, which yielded negative results [4]. For Piplia Kalan (PK), a recent fall [5], Al-Mg measurements were obtained by ion microprobe, in areas of plagioclase crystals with very high ^{27}Al/^{24}Mg (in excess of 3,000). The data defined an initial $(^{26}Al/^{27}Al)_0 = (7.5\pm0.9)\times10^{-7}$ [3]. These authors also clearly noted [3] that the pyroxene contained normal Mg and that the plagioclase contained excesses of ^{26}Mg, but that these excesses showed little variation with ^{27}Al/^{24}Mg, implying that the Al-Mg system was disturbed.

Results: In our preliminary work, last year, on the Lunatic I mass spectrometer using techniques described earlier [6] we found: (a) the same reproducible and limited range of instrumental mass fractionation, defined by ^{25}Mg/^{24}Mg (Δ^{25}Mg = -15±1.5‰/amu, for normal Mg), as reported earlier in all work from this laboratory; (b) a positive shift in the ^{26}Mg/^{24}Mg ratio, corrected for the instrumental mass fractionation, as observed for Mg standards; and (c) an independent negative shift in the corrected ^{26}Mg/^{24}Mg ratio, for mass spectrometric analyses in which a significant intensity of a $^{27}Al^+$ ion beam was observed, relative to the $^{24}Mg^+$ ion beam; this shift is consistent with prior experience for Mg analyses of directly loaded samples, in which $^{27}Al^+$ is present [7]. Because of the importance of the excess ^{26}Mg and the possible presence of ^{26}Al at the time of formation of this meteorite, we undertook to clarify further the nature of these shifts. We also purified the Mg from plagioclase further, in order to reduce the Al tail from the chemical separation and to eliminate the negative shift as noted under (c), above.

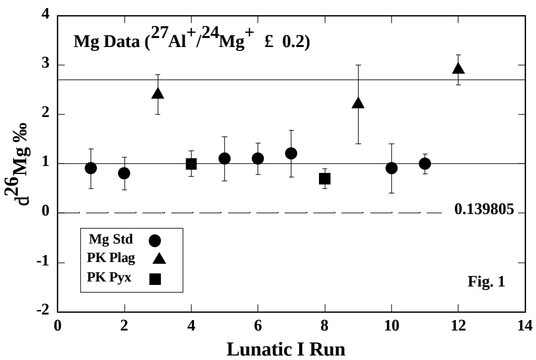
We report instrumental fractionation data as $\Delta^{25}Mg = [(^{25}Mg/^{24}Mg)_{meas.}/(^{25}Mg/^{24}Mg)_{ref.} -1]\times1000$, using ^{25}Mg/^{24}Mg= 0.12663 as the reference value [6]. For ^{26}Mg/^{24}Mg, to avoid confusion, we report all data, after correction for instrumental fractionation, as permil deviations (δ^{26}Mg), relative to ^{26}Mg/^{24}Mg = 0.139805, which is the value reported from this laboratory for earlier work [6, 7, 8], and not subject to the positive shift under (b), above. We show, in Fig. 1, a time series of new measurements of Mg on the Lunatic I, with low $^{27}Al^+/^{24}Mg^+$ (<0.2). Under this condition, all measurements of Mg standards (Johnson Matthey high purity Mg, obtained as metal and as MgO) are very tightly clustered and reproducible at (δ^{26}Mg) = 1.0 ± 0.1 ‰. This represents a constant and reproducible shift, relative to the earlier value for normal Mg. The reason for this shift is not established. However, in the intervening time, we introduced in the mass spectrometer analyzer tube, after the magnet, a baffle for the purpose of reducing scattered ion beams and improving the abundance sensitivity of the instrument, especially for U and Th. We have not removed this baffle to investigate whether this shift in ^{26}Mg/^{24}Mg would be eliminated. However, since the shift is constant and the results for standards are reproducible, we consider the Mg data to be reliable.

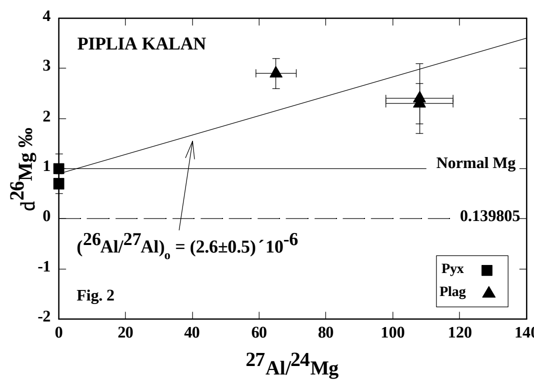
Two analyses of Mg from Piplia Kalan (PK) pyroxene are consistent with the analyses for the Mg standards, indicating the absence of an excess of ^{26}Mg in this high-Mg, low-Al/Mg PK phase. In Fig. 1, we also show our previous and new results on PK plagioclase density mineral separates. For the mineral separations, materials were sieved to be in the interval of 44-60 µm, and 60-125 µm in order to minimize binary grains, although microscopic inclusions in plagioclase of high-Mg phases can not be avoided. We have analyzed plagioclase separates with densities < 2.75 g/cm^3 and 2.70-2.80 g/cm^3 (Table 1). We also separated plagioclase crushed to < 44 µm, but it contained too much Mg and its isotopic composition was not measured. To minimize the intensity of $^{27}Al^+$ during the Mg mass spectrometric analysis, the Mg from plagioclase was separated using three passes through a cation exchange column. Using this procedure, $^{27}Al^+/^{24}Mg^+$ was kept at below 0.2 and in the same range as for Mg normals (with a small $^{27}Al^+$ contribution from the Si-gel). In the range for $^{27}Al^+/^{24}Mg^+<0.5$, no negative shifts in δ^{26}Mg have ever been observed. Both plagioclase samples show a small but distinct excesses δ^{26}Mg = 2.3±0.3 ‰ and δ^{26}Mg = 2.9±0.3 ‰. These data demonstrate that PK plagioclase shows a definite excess in ^{26}Mg (relative to δ^{26}Mg = 1 ‰ for Mg standards) while PK pyroxene has normal ^{26}Mg/^{24}Mg composition (also relative to the Mg standards, in this work).

In Table 1, we show all the data. We include analyses with high $^{27}Al^+/^{24}Mg^+$ for PK plagioclase and for a Mg standard that we doped with Al. Relative to the analysis of the Mg standard doped with Al (which is shifted by 2 ‰, to δ^{26}Mg = –1.0 ‰) the plagioclase analyses with high $^{27}Al^+/^{24}Mg^+$ also show excess ^{26}Mg.

However, we consider these data less reliable and will not use them.

The Mg concentrations in PK plagioclase were determined on small aliquots of the dissolved samples, by isotope dilution, using ^{25}Mg as the tracer and a separate ion source than the ion source used for the unspiked Mg analyses and kept free of the ^{25}Mg tracer. The best-fit line through the PK plagioclase and pyroxene data (Fig. 2) yields an initial $(^{26}Al/^{27}Al)_0 = (2.6 \pm 0.5) \times 10^{-6}$. The initial $(^{26}Mg/^{24}Mg)_0$ in PK, as established by the pyroxene, is normal and equal to 0.8 ± 0.2‰, relative to $^{26}Mg/^{24}Mg$ = 0.139805, or equal to –0.2 ± 0.2‰, relative to the Mg normal in this work. We note, however, that the plagioclase analyses do not fall precisely on the best-fit line, within uncertainties. The data by TIMS on the plagioclase could be interpreted as indicating a uniform, elevated $^{26}Mg/^{24}Mg$ value, essentially independent of $^{27}Al/^{24}Mg$ in the plagioclase.





Conclusions: We view the evidence for ^{26}Al in Piplia Kalan, by TIMS, as consistent with the data from the ion microprobe. We conclude that there appear to be definite excesses of ^{26}Mg in plagioclase in the Piplia Kalan eucrite. The excesses, which do not appear to be well correlated with Al/Mg in the plagioclase, are indicative of the remobilization of Mg isotopes in the plagioclase. This process within the plagioclase may be aided by the fact that this phase does not readily accommodate Mg. The difference in the inferred initial ^{26}Al abundance between Allende CAIs and PK suggests a time interval of ~3 Ma. We consider PK as a planetary differentiate, produced in the presence or due to the presence of ^{26}Al and cooled sufficiently fast to preserve evidence of further ^{26}Al decay, in a high Al/Mg phase. We consider that the excess ^{26}Mg was remobilized within the plagioclase subsequent to the decay of ^{26}Al. This remobilization or metamorphism was not so extensive for the Mg in the plagioclase and pyroxene to completely equilibrate and remove the resolvable δ^{26}Mg effects. This has permitted Piplia Kalan to retain some vestiges of its earliest formation. The low Rb-Sr age [9, 10], and the possible absence of effects for the ^{53}Mn-^{53}Cr system [1] could reflect this partial remobilization. Additional measurements, including the measurement of isotopically enriched Mg standards, are in progress in order to strengthen the case for well-defined excesses in ^{26}Mg in Piplia Kalan.

References: [1] Srinivasan et al. (1999) *LPSC XXX* #1730. [2] Srinivasan et. al. (1998) *MAPS* **33** A148. [3] Srinivasan et al. (1999) *Science* **284** 1348-1350. [4] Schramm et al. (1970) *EPSL* **10** 44-59. [5] Shukla et al. (1997) *MAPS* **32** 611-615. [6] Lee et al. (1976) *GRL* **3** 109-112. [7] Lee et al (1977) *GCA* **41** 1473-1485. [8] Wasserburg G.J. and Papanastassiou D.A. (1982) *Essays in Nuclear Astrophysics* (Eds. Barnes et al.) pp.77-140. [9] Kumar et al. (1999) *GCA* **63** 3997-4001. [10] Srinivasan et al. (1999) *LPSC XXX* # 1718. Work Supported by NASA, NAG5-8251. Division Contribution No. 8658(1050).

Table 1. Mg Data

SAMPLE	$(^{27}Al^+/^{24}Mg^+)^a$	$\Delta^{25}Mg^b$ ‰/amu	$\delta^{26}Mg^c$ ‰
Low $^{27}Al^+/^{24}Mg^+$ (≤ 0.2) Runs			
Mg Std[d]	0.1	-16.8 ± 0.3	0.9 ± 0.4
	0.1	-16.5± 0.2	0.8 ± 0.3
	0.2	-13.5± 0.3	1.1 ± 0.5
	0.1	-13.1± 0.4	1.1 ± 0.3
	0.1	-14.0 ± 0.2	1.2 ± 0.5
	0.2	-15.7 ± 0.2	0.9 ± 0.5
	0.2	-16.1 ± 0.2	1.0 ± 0.2
AVERAGE	≤ 0.2	-15.3 ± 0.1	1.0 ± 0.1
PK- PYX	0.1	-14.3 ± 0.1	1.0 ± 0.3
PK- PYX	0.1	-13.6 ± 0.2	0.7 ± 0.2
PK-PL-1	0.2	-14.0 ± 0.5	2.9 ± 0.3
PK-PL-2[e]	0.2	-16.1 ± 0.2	2.3 ± 0.4
PK-PL-2	0.2	-12.7 ± 0.4	2.4 ± 0.7
High $^{27}Al^+/^{24}Mg^+$ (> 0.5)Runs			
Mg Std[f]	2	-17.4 ± 0.1	-1.0 ± 0.2
PK-PL-1	2	-15.6 ± 0.4	-0.2 ± 0.6
PK-PL-1	0.6	-14.0 ± 0.9	1.7 ± 0.8
PK-PL-1	1	-11.6 ± 0.1	1.5 ± 0.2

[a]Intensity ratio of ^{27}Al and ^{24}Mg measured during the run. [b]Isotope fractionation using $^{25}Mg/^{24}Mg$ = 0.12663. [c]Corrected for Δ^{25}Mg; deviations in $^{26}Mg/^{24}Mg$ relative to $(^{26}Mg/^{24}Mg)_N$ =0.139805. [d]Johnson Matthey (JM) Mg. [e]Reported in [1]. PK-PL-1 (ρ <2.8 g/cm3, size: 60-125µm, Mg ~ 3900ppm, Al ~ 20%). PK PL-2 (ρ < 2.75 g/cm3, size: 40-60µm, Mg ~ 2400 ppm, Al ~ 20 %). PK Pyx (ρ > 3.3 g/cm3, size: 60-125µm, Mg ~6%, l <0.1%). [f]JM Mg doped with Al.