

^{26}Al - ^{26}Mg AND ^{53}Mn - ^{53}Cr SYSTEMATICS IN THE PIPLIA KALAN EUCRITE. G. Srinivasan^{1,2}, D. A. Papanastassiou¹, G. J. Wasserburg¹, N. Bhandari², and J. N. Goswami². ¹The Lunatic Asylum of the Charles Arms Laboratory, Division of Geological and Planetary Sciences, California Institute of Technology 170-25, Pasadena, CA 91125; ²Physical Research Laboratory, Navrangpura, Ahmedabad, 380 009 India (srini@gps.caltech.edu).

We report results on the ^{26}Al - ^{26}Mg and ^{53}Mn - ^{53}Cr systems, in the Piplia Kalan eucrite, using thermal ionization mass spectrometry (TIMS). In a recent report, Srinivasan et al. [1] identified the presence in this eucrite of excess ^{26}Mg , correlated with Al/Mg. This report [1] was the first of clear excess ^{26}Mg in a eucrite. The analyses were obtained by ion microprobe measurements of Al-Mg in areas of plagioclase crystals with very high Al/Mg (in excess of 3,000). The data defined an initial $^{26}\text{Al}/^{27}\text{Al} = (7.5 \pm 0.9) \times 10^{-7}$. Because of the importance of this report, we undertook to confirm the Mg results by thermal ionization mass spectrometry and to extend the measurements to the Mn-Cr system. In a separate abstract, we present the results of the work on the $^{147,146}\text{Sm}$ - $^{143,142}\text{Nd}$ systems [2]. Piplia Kalan is a recent fall in India [3]. It is a monomict eucrite and consists of lithic clasts in a brecciated matrix. Lithic clasts show a large range in grain size and texture [3, 4] but similar bulk compositions, consistent with a single melt event. Major phases are pyroxene (55-65%) and plagioclase (25-45%), with chromite, ilmenite, and troilite as minor phases. The plagioclase crystals from PK contain abundant microscopic inclusions, consisting mostly of pyroxene. As a result, for the Al-Mg work, the main challenge has been to obtain plagioclase crystals with high Al/Mg, free of these Mg-bearing microscopic inclusions. At this time, the work on individual crystals is proceeding, but we are reporting results on bulk density mineral separates. We obtained plagioclase separates by density and magnetic separations. The Mg concentrations (Table 1) have been determined by isotope dilution on small aliquots of the dissolved samples. The Al concentrations are assumed to be the stoichiometric values, at $\approx 20\%$. We measured the Mg isotopic composition and concentration in one plagioclase separate, PK-PL-1 ($\rho < 2.80 \text{ g/cm}^3$, 60-125 μm). To reduce the Mg in the bulk plagioclase, we then used material crushed more finely and separated at a slightly lower density, closer the density of the pure plagioclase, (PK-PL-2, $\rho < 2.75 \text{ g/cm}^3$, 44-60 μm). The results are shown in Table 1. We note an improvement in the Mg content from the first to the second plagioclase separate. In Table 1, we list two analyses of normal Mg (Johnson Matthey Mg) which yield $^{26}\text{Mg}/^{24}\text{Mg}$ higher, by 0.8 and 1%, than our previously determined reference value for $^{26}\text{Mg}/^{24}\text{Mg}$ ($\equiv 0.139805$). Repeat measurements are required to confirm this possible shift. An additional technical issue involves the well-documented shift in $\delta^{26}\text{Mg}$ by -1.5 ‰, when, during the mass spectrometer analysis, there is a substantial $^{27}\text{Al}^+$ beam present (ion beam ratios $^{27}\text{Al}^+ / ^{24}\text{Mg}^+ \geq 0.5$) [5]. We doped an aliquot of the Mg normal with Al (JM Mg #3, Table 1) and observed this shift for $^{27}\text{Al}^+ / ^{24}\text{Mg}^+ \approx 2$. For the data in Table 1, the analysis of PK-PL-2 may be subject to this shift. Because

the observed $^{27}\text{Al}^+ / ^{24}\text{Mg}^+$ for PK-PL-2 is close to the applicable limit, we have taken a conservative approach with regard to evidence for ^{26}Mg excesses. We have not applied the additive correction factor of 1.5 ‰, to the data reported in Table 1. All other Mg analyses had low $^{27}\text{Al}^+ / ^{24}\text{Mg}^+$ and did not require a correction. To remain equally conservative, we also consider the observed $\delta^{26}\text{Mg}$ for the PK plagioclase analyses relative only to the elevated $\delta^{26}\text{Mg}$ for the Mg normal, in Table 1 and Fig. 1. A comparison shows that the $\delta^{26}\text{Mg}$ value for PK-PL-2 is clearly higher and resolved from the value for the Johnson Matthey Mg standard (undoped). The $\delta^{26}\text{Mg}$ for PK-PL-1 is not clearly resolved. We show the data in Fig. 1. We assume that the excesses in $^{26}\text{Mg}/^{24}\text{Mg}$ are attributable to ^{26}Mg . These data appear to confirm the results obtained by the ion microprobe, on spots within plagioclase crystals free of the microscopic inclusions and with much higher $^{27}\text{Al}/^{24}\text{Mg}$, in the range of 3,000-7,000 [1]. From the TIMS data on the plagioclase, in combination with the analyses on the Mg normal, we calculate the initial $(^{26}\text{Al}/^{27}\text{Al})_0 = (1.6 \pm 0.6) \times 10^{-6}$. We view these results as consistent with the value deduced from the ion microprobe data, $(^{26}\text{Al}/^{27}\text{Al})_0 = (7.5 \pm 0.9) \times 10^{-7}$ [1]. The implied time difference between the canonical $(^{26}\text{Al}/^{27}\text{Al})_0$ for Ca-Al-rich inclusions and for PK is ≈ 4 Ma. However, we note that we have not yet measured the Mg isotopes in Mg-rich phases (pyroxene) in PK, in order to determine directly the initial $^{26}\text{Mg}/^{24}\text{Mg}$ in PK and in order to ascertain that the initial $^{26}\text{Mg}/^{24}\text{Mg}$ in PK is not elevated. We also plan to extend the measurements to single plagioclase crystals, by the modified direct loading technique [5]. The pervasive nature of microscopic, Mg-rich (pyroxene) inclusions and alteration within the plagioclase will require a substantial effort to obtain pure plagioclase, with high Al/Mg.

We have also initiated a study of the Mn-Cr system. For the preliminary data in Table 2, we report results for individual mass spectrometer runs, using the Lunatic I, in a dynamic mode. Uncertainties can be improved by repeat analyses of aliquots of a sample [6]. We also attempted static data collection on the Finnigan/MAT 262 multiple Faraday cup mass spectrometer. We found shifts for repeat analyses of normal Cr (of up to 1.5 ‰, for a 52-54, more limited dispersion, 2 amu, configuration) in the measured isotope ratios (corrected for isotope fractionation). These shifts are presumably associated with the large mass dispersion of the Cr isotopes. Therefore, static data collection is not possible with instruments currently in use (cf also G. Lugmair, pers. commun.). A PK pyroxene sample was obtained by density separation, followed by handpicking, to remove grains with identifiable microscopic chromite inclusions. The ^{53}Cr data obtained on the PK pyroxene, and using the normal Cr measurement in Table 2, do not show an excess in ^{53}Cr in

this eucrite. This observation is distinct from the observation of excesses in ^{53}Cr in the range of 1‰ for non-cumulate eucrites, for samples with lower $^{55}\text{Mn}/^{52}\text{Cr}$ of 2-3 [6]. From our data for ^{53}Cr in normal Cr and in PK pyroxene we calculate an upper limit to the initial $^{53}\text{Mn}/^{55}\text{Mn} \leq 1.9 \times 10^{-6}$. With an improvement in the uncertainties in this work by repeat measurements, it should be possible to establish tighter limits or a resolved lower value for the initial $^{53}\text{Mn}/^{55}\text{Mn}$ in this eucrite. Based on the observation of ^{26}Mg excesses in PK, we would have expected to obtain a significant initial $^{53}\text{Mn}/^{55}\text{Mn}$ at the time of formation of PK. The results, at this time, imply some discrepancy, as was also observed for the ^{146}Sm - ^{142}Nd system [2]. The short-lived systems (^{26}Al - ^{26}Mg , ^{53}Mn - ^{53}Cr , and ^{146}Sm - ^{142}Nd) appear to give results which are not easily reconcilable. However, the strong hint for the presence of ^{26}Al in PK is of critical importance in

identifying a heat source for early planetary evolution and this work on PK will be pursued vigorously.

Acknowledgment: Work supported by NASA. Division Contribution No.8604 (1022).

References: [1] Srinivasan G., Goswami J.N. & Bhandari N. (1998) *Meteoritics Planet. Sci.* **33** A148. [2] Srinivasan G. et al. (1999) This Conference. [3] Vaya V.K. et al. (1996) *Current Science* **71** 254. [4] Shukla A. et al. (1997) *Meteoritics Planet. Sci.* **32** 611. [5] Lee T., Papanastassiou D. A. & Wasserburg G.J. (1977) *Geochim. Cosmochim. Acta* **41** 1473. [6] Lugmair G.W. & Shukolyukov A. (1998) *Geochim. Cosmochim. Acta.* **62** 2863. [7] Papanastassiou D. A. (1986) *ApJ (Letters)* **308** L27.

Table 1. Piplia Kalan Al-Mg Analytical Results

Sample	Mg [‡] (ppm)	(²⁷ I/ ²⁴ I) ^{‡‡} (ppm)	▶ ²⁶ Mg ^{**} (permil)
PK-PL-1 (<2.80 g/cm ³ , 60-125 ▶ m)	3280	~ 0.6	1.72±0.77
PK-PL-2 (<2.75 g/cm ³ , 40-60 ▶ m)	2010	~ 0.2	2.28±0.43
JM Mg #1 [†]		0	1.01±0.48
JM Mg #2 [†]		0	0.83±0.33
JM Mg #3, Doped*		~ 2	1.04±0.19

[†]Johnson Matthey Mg. *JM Mg doped with Al.

[‡]Mg concentrations determined by isotope dilution.

^{‡‡}Ratio of ion counts measured during the run.

**Data corrected for isotope fractionation using $^{25}\text{Mg}/^{24}\text{Mg} = 0.12663$; deviations in $^{26}\text{Mg}/^{24}\text{Mg}$ relative to $(^{26}\text{Mg}/^{24}\text{Mg})_{\text{N}} = 0.139805$.

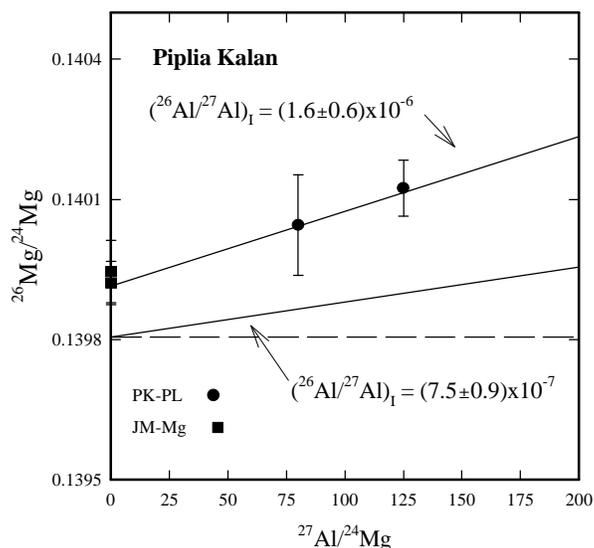


Table 2. Piplia Kalan Mn-Cr Analytical Results

Sample	Mn (ppm)	Cr (ppm)	$^{55}\text{Mn}/^{52}\text{Cr}$	▶ ^{53}Cr [*] (epsilon)
PK-PX-2	9000	1400	7.2	0.39±0.71
Cr Standard #1				0.85±0.69

*Data normalized for instrumental fractionation using $^{50}\text{Cr}/^{52}\text{Cr} = 0.051859$. Deviations in ^{53}Cr (in parts in 10⁴) from $^{53}\text{Cr}/^{52}\text{Cr} = 0.113447$ [7].