SIDEROPHILE ELEMENTS IN BRECCIATED LUNAR METEORITES. R. L. Korotev, Campus Box 1169, Department of Earth & Planetary Sciences and McDonnell Center for the Space Sciences, Washington University, Saint Louis, MO 63130; korotev@wustl.edu

The presence of moderately high levels, compared to terrestrial abundances, of SEs (siderophile elements) of asteroidal origin in lunar breccias and soils was the focus of considerable interest in early studies of Apollo samples [e.g., 1–3]. The existence now of lunar meteorites, which are near-surface sample from all over the Moon, provides a new opportunity to consider SE abundances and their sources in materials of the lunar surface.

Unbrecciated igneous and plutonic rocks of the lunar crust have very low concentrations of highly SEs like Ir (typically 0.001–0.1 ng/g [4]). Polymict samples derive SEs from three sources [1,5]: (1) micrometeorites, mainly CM chondrites, (2) macrometeorites that formed craters, mainly ordinary chondrites, and (3) asteroids that formed the basins >3.8 Ga ago. In the vicinity of the Apollo sites, at least, the latter appear *not* to have been ordinary chondrites [6–9].

I obtained the data presented here by INAA using methods previously described [10]. Numerous subsamples of each meteorite were analyzed. Data for mass-weighted means of all subsamples of each meteorite are presented in Fig. 1 and data for individual subsamples of some meteorites in Fig. 2.

Ni/Ir concentrations vary among different classes of meteorites, particularly irons [11]. Most brecciated lunar meteorites have Ni and Ir concentrations consistent with mixture of indigenous lunar material having ~0 ng/g Ir and 15 ± 10 µg/g Ni and ordinary chondrites or CM chondrites (Fig. 1). A number do not. The meteoritic components of most of the outliers of Fig. 1 have higher Ni/Ir than ordinary chondrites. In contrast, for NWA 081 (and pairs), MAC 88104/5, and Dhofar 1527, Ni/Ir is subchondritic. Data for multiple subsamples largely confirm that the anomalies implied by Fig. 1 (means) are shared by most subsamples (Fig. 2). NWA 4936/5406 is an exception as the two high-Ir subsamples are different from the trend of the numerous low-Ir subsamples

The Apollo 16 regolith lies outside the range of chondrites (Fig. 1), and the reason is well understood [6,7]. About half the Ir (~6 ng/g) is contributed by chondritic micro- and macrometeorites (cyan diagonal square in Fig. 1 inset) whereas the other half is contributed by ancient (3.9 Ga), mafic, metal-rich IMBs (impact-melt breccias) with subchondritic Ni/Ir. The IMBs appear to contain FeNi metal derived from a group-IAB-like iron meteorite [6–8]. NWA 4936 and pairs are very similar in composition to Apollo 16 soil and likely also originate in or near the Cayley Plains. NWA 4936 plots on the Apollo 16 mixing line of Fig. 1 and likely contains a higher proportion of the same type of metal as is found in the Apollo 16 mafic IMBs.

Other Ni/Ir-anomalous meteorites (Dhofar 1527, Dhofar 1627, and NWA 4884, NWA 5000) are also described to be rich in metal or have large metal grains – too rich or too large for the metal to have derived from chondrites. The lunar meteorites imply that iron meteorites contribute more to the siderophile-element budget of lunar surface materials than their relative abundance among modern falls (4.4%) suggests. Even 0.1% iron meteorite in a lunar breccia, however, will significantly affect siderophile element concentrations and may affect SE ratios.

Table 1. Mean concentrations in many samples.

	N	FeO_t %	Co µg/g	Ni µg/g	Ir ng/g	Ni/Ir
FLMs of Fig. 1	62	5.53	21.5	223	9.0	2.48×10^4
all LMs of Fig. 1	71	6.51	23.9	226	9.0	2.51×10^4
A16 S&T	42	5.14	28.2	391	12.5	3.13×10^4

FeO_t = total Fe as FeO; N = 62 FLMs (Fig. 1, those with <10% FeO_t), all 71 samples of Fig. 1; and 42 samples of surface and trench soils from Apollo 16 (references of [12]).

On average, Ni and Ir concentrations in FLMs (feldspathic lunar meteorites) are about 57% and 72% those of Apollo 16 soils (Table 1). The differences probably reflect the high abundance of metal from metal-rich impact-melt breccias at the Apollo 16 site. On

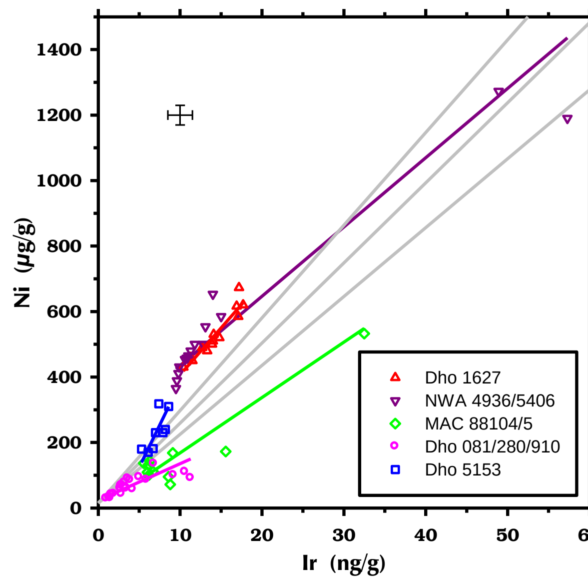

Figure 2. Subsample data for some of the non-chondritic samples of Fig. 1. The long gray lines are the ordinary-chondrite lines of Fig. 1 and the short colored lines are least- squares fits to the 5 sets of data. For 90% of the points, the analytical uncertainty (1 SD) is that indicated by the error bars or smaller.

average, mean concentrations of Ni and Ir in lunar meteorites (Table 1, Fig. 1 inset) correspond to 1.6% CM chondrite or 1.8% L chondrite. These value are good estimates for the surface of the feldspathic highlands.

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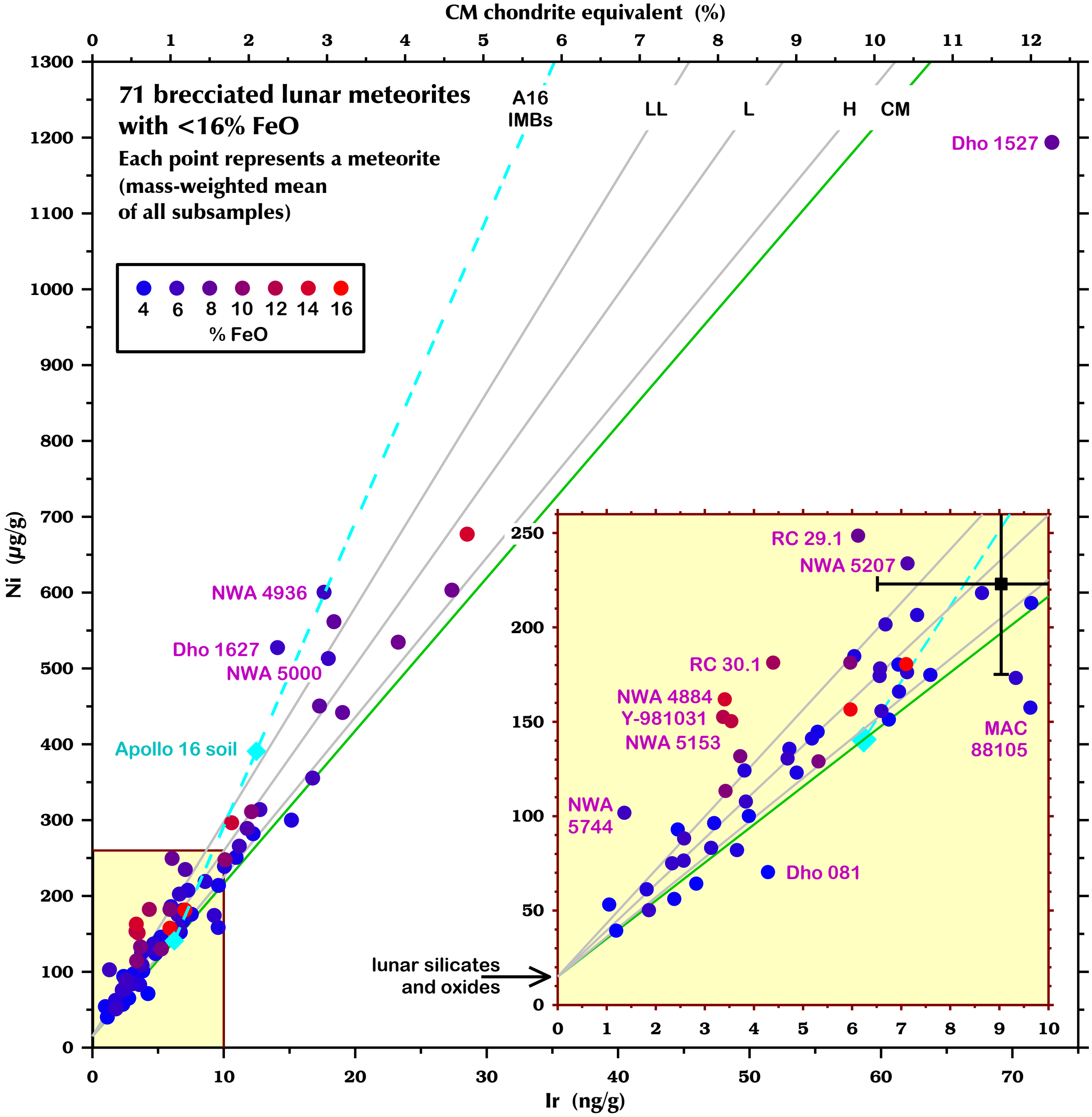

Figure 1. Each circle represents a lunar meteorite. All but 9 are feldspathic in having <10% FeO. Most of the meteorites plot in the field corresponding to mixtures of indigenous lunar material (~0 ng/g Ir and 15 ±10 µg/g Ni) and ordinary (H, L, LL, gray lines) or CM chondrites (green line). Several, at least, of those plotting outside the chondritic field are rich in metal. (NWA 5744 is not, but is a brecciated troctolitic anorthosite that may have a higher indigenous Ni concentration than the 15 µg/g assumed here.) The cyan line is defined by Apollo 16 soil (Table 1) and mafic, metal-rich impact-melt breccias of Apollo 16 [7]. Its extrapolation into the chondrite field implies that the Apollo 16 regolith contains the equivalent, for example, of 1.05% CM chondrite or 1.6% L chondrite. In the inset, the black square represents the mean of the 62 feldspathic lunar meteorites (Table 1). The error bars are 95% confidence limits, which are not particularly meaningful given the non-Gaussian distributions.