LUNAR SURFACE GEOCHEMISTRY AND LUNAR METEORITES. R. L. Korotev, Campus Box 1169, Dept. of Earth and Planetary Sciences, Washington University, Saint Louis MO 63130; korotev@wustl.edu

Since 1979, about 136 lunar meteorite stones from ~65 meteorites representing not more than ~45 craters on the Moon have been found of Earth. The meteorites provide a different type of information than the rocks of the Apollo collection because the derive from randomly distributed locations over the whole Moon whereas the Apollo samples all derive from in or near the geochemically anomalous PKT (Procellarum KREEP Terrane). For none of the lunar meteorites is the source crater actually known [1–3]. Presumably because of the global sampling provide by the meteorites, they demonstrate that the lunar crust is more diverse than can be easily inferred from the Apollo collection.

Ten of the meteorites are, or contain large clasts of, unbrecciated basalt. Three others are breccias consisting nearly entirely of basalt. In detail, none of basaltic lunar meteorites is a compositional match to any of the basalts from the Apollo and Luna collections, although some are similar to the basalts of Apollo 12 and, to a lesser extent, Apollo 15. None is a high-Ti basalt (>6% TiO_2), such as those from Apollo 11 and 17 (Fig. 1b). Some of the basaltic meteorites are very different from any in the Apollo and Luna collections [4–8]. The NWA 773 clan of lunar meteorites includes some stones that are dominated by cumulate olivine gabbro, a lithology that does not occur in the Apollo collection [9,10].

All other lunar meteorites are breccias, i.e., they are mechanical mixtures of more primary rock types. More than half of the lunar meteorites are regolith or fragmental breccias. Such breccias are, in effect, sedimentary rocks in that they are composed mainly of shock-lithified material that existed near the surface of the Moon. As such, their compositions and mineralogies likely reflect the material that would be sensed remotely from orbit in the vicinity of their respective source craters. Others are impact-melt and granulitic breccias that may represent material from deeper in the crust. (The author suspects that many of the lunar meteorites that have been classified as impact-melt breccias are not, in fact, crystalline or glassy melt breccias as defined by [11] in that the matrix was never largely molten. Many of the nominal “impact-melt breccias” may well also represent near-surface material.)

More than half the lunar meteorites have composition that are consistent with derivation from the feldspathic highlands in that they have low concentrations of FeO (Fig. 1c) and incompatible elements (Fig. 1e). Nearly all have concentrations of incompatible elements that are lower than those of Apollo 16 soils (Fig. 1f) because of the Apollo 16 site’s proximity to the PKT [12,13]. On average, feldspathic lunar meteorites (somewhat arbitrarily, those with <7.7% FeO) have compositions that corresponds to noritic anorthosite with 78 mass % plagioclase (Table 1). On average, the proportion of iron carried by pyroxene is about the same as that carried by olivine. The principal compositional difference among the feldspathic lunar meteorites is the ratio of MgO to FeO (Fig. 1a). *Mg´* (mole % Mg/[Mg+Fe]) is highly variable, ranging from 57 to 78 and averaging 67. *Mg´* tends to increase with normative olivine [12]. The high *Mg´*, compared to ferroan anorthosite, of feldspathic lunar meteorites, indicates that magnesian anorthosites exist somewhere in the lunar crust [12–15]. Whether the *Mg´* variation is primarily lateral or vertical in the feldspathic highlands is a first order question.

Table 1. Mean of 36 feldspathic lunar meteorites, with normative mineral abundances (mass %) and calculated volume abundances.

	mass %		mass %	vol. %
SiO_2	44.7	plag	78	82
TiO_2	0.25	opx	9	7
Al_2O_3	27.9	cpx	5	4
Cr_2O_3	0.11	ol	8	7
FeO	4.76	ilm	0.5	0.3
MnO	0.07		100.5	100.3
MgO	5.50			
CaO	16.2	from Antarctic CaO/Al_2O_3 ratio		
Na_2O	0.37			
K_2O	0.03	Antarctic only		
P_2O_5	0.03	Antarctic only		
	100.0	mean *Mg´* = 67%		

Lunar meteorites with intermediate concentrations of FeO are the most compositionally and petrographically diverse. Three (5% of total) are almost certainly from the PKT (Fig. 1e). None of the three breccias has a composition that matches any of the Apollo soils (Fig. 1f). Some intermediate FeO meteorites clearly derive from a region of mare-highlands mixing because they consist of both basalt and feldspathic breccias. Others, however, do not obviously have a significant basalt component and may represent mafic areas in the highlands or perhaps some type of nonmare volcanism. At least one lunar meteorite has composition and mineralogy consistent with derivation from the South Pole-Aitken basin [3,16].

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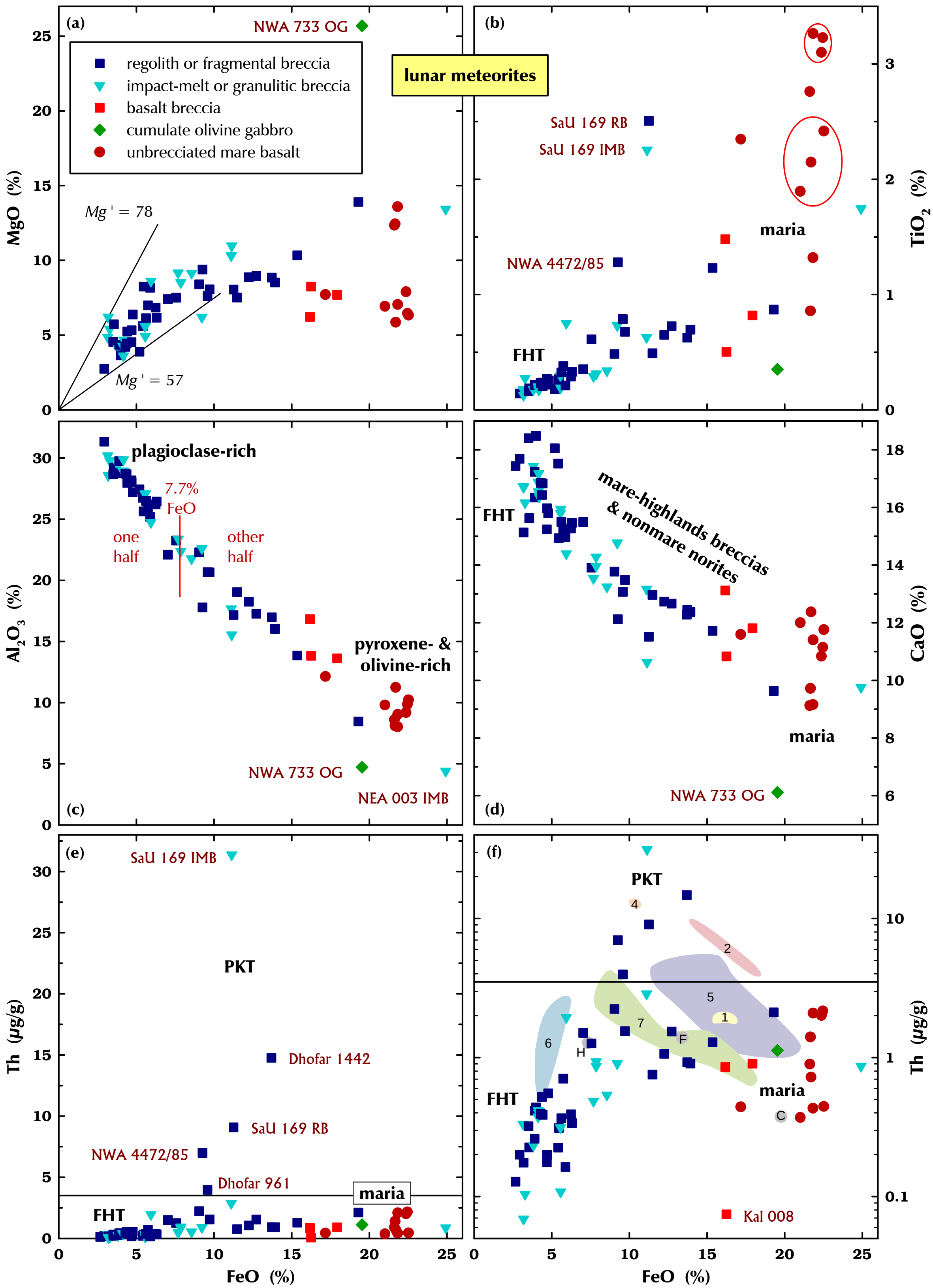

Figure 1. Compositions of lunar meteorites. (a) Diagonal lines show the range of *Mg´* for feldspathic lunar meteorites. (b) Ellipses enclose meteorites from the same source crater. (c,d) Plagioclase – pyroxene+olivine+ilmenite mixing. (e, linear) Most meteorites with >3.5 µg/g Th likely come from the Procellarum KREEP Terrane; Dhofar 961 may be from South Pole-Aitken [x]. (f, logarithmic) Comparison to soils from the Apollo (1=11, etc.) and Luna (F=16, H=20, C=24) missions.