FENI METAL GRAINS IN LA PAZ MARE BASALT METEORITES AND APOLLO 12 BASALTS.

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Introduction: The LaPaz mare basalt meteorites and Apollo 12 basalts contain FeNi metal grains with anomalously high Ni and Co abundances, unlike those found in typical achondrites, chondrites, or iron meteorites. In Apollo 12 basalts, FeNi metal grains are associated with the earliest formed minerals (chromite and olivine) and are often at the boundaries between the phenocrysts and the matrix. Conversely in the LaPaz mare basalts, the FeNi metal grains are sited within the Fe-rich rims of pyroxene, or at the boundaries of pyroxene, plagioclase, or ulvöspinel, indicating late-stage formation. The disparate FeNi metal crystallization sequence of the Apollo 12 and LaPaz basalts, all of which formed at low oxygen activities, probably represents the control of phases with relatively high partition coefficients for Ni and Co, such as olivine and chromite. Formation of metal grains may be the direct result of the crystallization of olivine and chromite in Apollo 12 basalts, whereas lack of olivine and chromite in LaPaz basaltic melts may 'force' crystallization of FeNi metals due to their relative incompatibility.

Results: The general petrography and geochemistry of the low-Ti LaPaz lunar mare basalts are described elsewhere [1,2]. We have also re-analyzed Apollo 12 samples that have been shown to possess FeNi metals with anomalously high abundances of Ni and Co [3].

Textures: The overall textures of the Apollo 12 and LaPaz basalts studied are very different with porphyritic textures for Apollo 12 basalts, and a more macrocrystalline, intergranular texture for the LaPaz basalts (e.g., Fig. 1). FeNi metals in both Apollo 12 and LaPaz basalts occur as rounded anhedral grains (Fig. 1). Apollo 12 FeNi metals are commonly found within, and at the grain boundaries of olivine and chromite (± ulvöspinel). The LaPaz FeNi metals generally occur at the boundaries of late-formed plagioclase, pyroxene, and ulvöspinel, or more commonly, within the extreme Fe-rich rims of pyroxene (e.g., Fig.1).

FeNi metal compositions: The FeNi metal compositons obtained during the course of this study for Apollo 12 basalts are presented in Fig. 2. Ni and Co contents in the Apollo 12 metals correlate positively and range from 0.4-37.4wt.%, and 0.8-6.5wt.%, respectively (Fig. 2). These results are comparable to previously published data [3-5], although one previous study has reported extreme abundances of up to 56wt.% for Ni and 9wt.% for Co [4]. Ni and Co contents in LaPaz metals

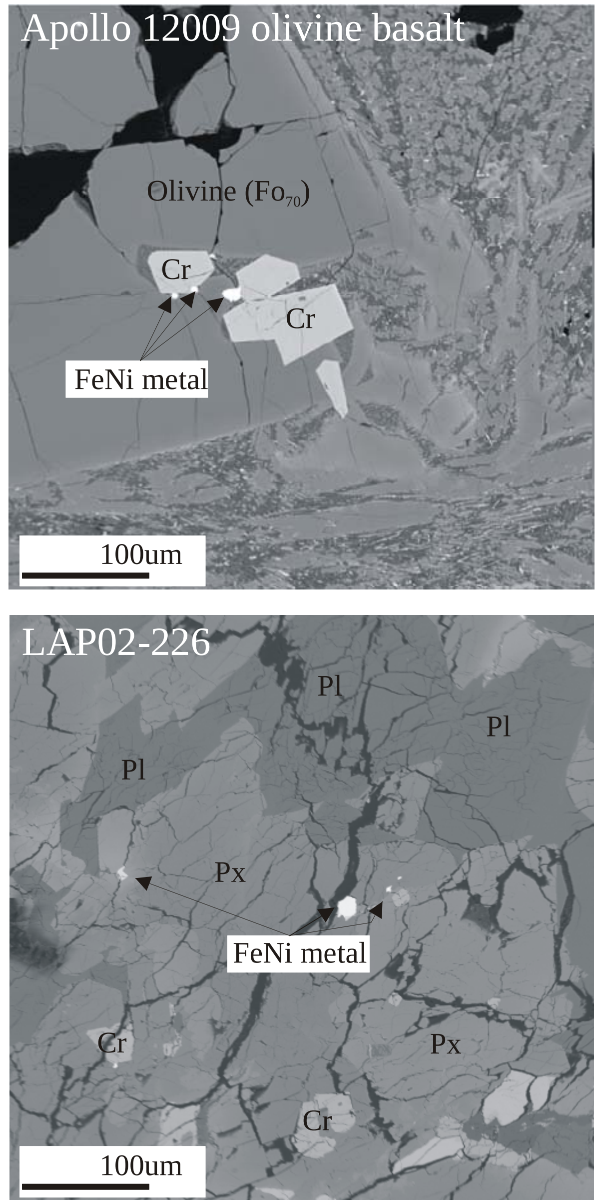

Fig. 1 – BSE images illustrating the sites of FeNi metals in Apollo 12009 and LAP02-226 mare basalts.

also correlate positively and with notably less scatter compared to Apollo 12 basalts. Ni and Co contents range from 0.01-37.5wt.% and 0.1-6.3wt.% respectively (Fig. 2). FeNi metals in the Apollo 12 and LaPaz basalts studied here do not show any systematic relationships between Co and Ni contents and location within their respective oxide and silicate host minerals.

A noteworthy anomaly for the LaPaz FeNi metals is the presence of a high Ni metal (61.4wt.% Ni, 2.5wt.% Co) located within a troilite inclusion framed within late-stage Fe-rich pyroxene (Fig. 3).

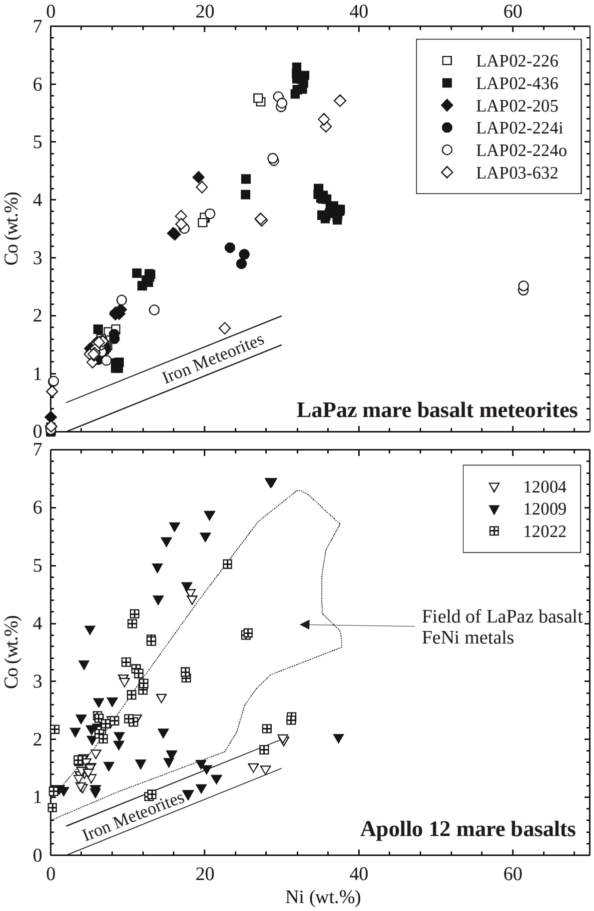

Fig. 2 – Ni versus Co abundances (in wt.%) for FeNi metal inclusions in LaPaz and Apollo 12 mare basalts.

Origin of FeNi Metal grains: Both the LaPaz and Apollo 12 mare basalts contain FeNi metals with elevated Co and Ni contents, which lie away from 'typical' iron, chondrite, or achondrite equivalents (e.g., Fig 2). Reid *et al.* [3], suggested the presence of these grains precluded an exogenous origin, based on Co and Ni contents, as well as metal grain morphologies [6]. This notion is in agreement with Re-Os isotope studies of the LaPaz mare basalts which would be highly sensitive to even minor additions of exogenous meteoritic material [2]. Immicible liquid separation has also been ruled out due to the unreasonably high temperatures required for this process to occur (~1500ºC), as well as the considerable problem of density constrast between silicate and metal resulting in gravitational separation [3]. Instead, Reid *et al.* [3] proposed that direct reduction and crystallization of the FeNi metals occurred

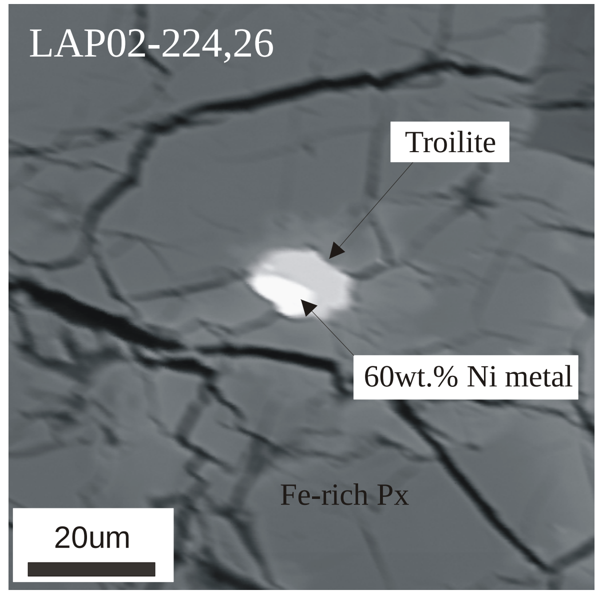

Fig 3. – BSE image of a metal grain with 61wt.% Ni next to a troilite.

during fractional crystallization of the silicate and oxide phases with the highest partition coeffiecients for Co and Ni (i.e., olivine and chromite). This process, although potentially valid for Apollo FeNi metals, does not seem appropriate for the LaPaz metals. Expectation would be for the high cobaltian and nickel metals to be hosted in early formed minerals, with a decrease in Ni and Co corresponding to metals formed later in the fractional crystallization sequence; the opposite is true.

Conclusions: The new results from the LaPaz FeNi basalts modify the hypothesis of Reid *et al.* [3]. If the Ni- and Co-rich FeNi metals formed early in the Apollo 12 crystallization sequence, then the late-stage formation of similar metals in the LaPaz basalts suggest that phases with high Ni and Co partition coefficients control FeNi metal formation. Absence of these phases (olivine, chromite) might result in 'overstaturation' of Fe, Ni and Co in the melt, because Co and Ni are forced into a state of relative incompatibility. The resultant consequence is the crystallization of these unique FeNi metals.

[1] Day J.M.D. *et al.* (2005) *LPSXXXVI,* this volume. [2] Day J.M.D., Pearson D.G., Taylor L.A. (2005) *LPSXXXVI,* this volume. [3] Reid A.M. *et al.* (1970) *EPSL*, 9, 1-5. [4] Brett R. *et al.* (1971) *LPSII*, 1, 301-317. [5] El Goresy A. *et al.* (1971) *LPSII*, 1, 219-235. [6] Spencer L.J. (1933) *Min. Mag.* 23, 387.