CHROMITE AND ILMENITE FRACTIONATION TRENDS IN HOWARDITES.

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Introduction: At the 42nd Lunar and Planetary Science Conference, [1] presented pyroxene Ti-Cr and Fe-Mg data from 11 howardites that suggests many howardites do not consist of unrelated rock fragments that were subsequently lithified, but rather contain diogenitic and eucritic fragments that form continuous and extensive fractional crystallization trends. Up to six types of patterns in pyroxene have been found so far. Here, we report on the chromite and ilmenite phases within most of those howardites to determine whether they are in agreement with this fractionation relationship. These minor phases are important because the timing of chromite and ilmenite crystallization prior to, during or after pyroxene formation is the primary cause of any change in the Ti-Cr vs Fe-Mg pattern observed in the pyroxene fractionation trends.

Results and Discussion: Oxides from 8 of the 11 howardites used in [1] were analyzed by electron microprobe. These include grains from lithic clasts and mineral fragments from Winterhaven, Bialystok, Le Teilleul, Petersburg, Bholghati, Chaves, Luotolax and Zmenj. The Fe-Mg-Ti-Cr-Al systematics within the chromites vary moderately between samples in modal abundance and compositional range when plotted in a Fe_2TiO_4-$FeCr_2O_4$-$FeAl_2O_4$ ternary. Chromite Ti concentrations are the most variable and increase with Fe/(Fe+Mg). Typically Al decreases with FFM and Cr is either somewhat steady or decreases. Bholghati, Luotolax, Zmenj and Le Teilleul all contain chromites with wide compositional ranges that include very Mg-rich (FFM~64-72) grains. These Mg-rich grains are consistent with derivation from the diogenitic component of the howardites based on the high proportion of diogenitic pyroxene previously measured in those samples [1,2,3]. Very Fe-rich chromites (FFM>0.9) found in many samples contain large variations in their concentrations of Al, Cr as well as Ti, possibly reflecting metamorphic alteration towards ulvospinel [4].

Compared to the compositional variations found in the chromites, the ilmenites are remarkably uniform. The only significant variation between the different howardite ilmenites is their range of Fe/(Fe+Mg) ratios, with Winterhaven having the most Mg-rich (FFM~86-95) and Bialystok the most Fe-rich (FFM~95-97). All 8 howardites have very low minor/trace concentrations in elements such as Al, Cr and Ca, with only Bialystok having mildly variable Al and Cr.

Conclusions: The distribution of chromite compositions is consistent with a fractional crystallization model to produce the full array of lithologies measured in the pyroxene. The ilmenites, though containing little trace element evidence measurable by electron microprobe, are also consistent with fractionation based on their range of FFM ratios.

The one unusual sample in this study is Zmenj, which shows a more convincing continuous compositional fractionation trend in chromite than pyroxene, possibly indicating the section analyzed is unrepresentative of this howardite.

References: [1] Boesenberg J. S. and Erb I. R. (2011) Lunar Planet. Sci. Conf. XLII, 1017. [2] Mittlefehldt D. W. et al. (1998) *Planetary Materials*, Reviews in Mineralogy (ed. by J. J. Papike), 4-1 – 4-195. [4] Mittlefehldt D. W. (1994) GCA 58, 1537-1552. [3] Arai T. et al (1998) Ant. Meteor. Res. 11, 71–91.