MINERAL ANALYSES OF HOWARDITE CLASTS AND A DIFFERENTIATION MODEL FOR THE BASALTIC ACHONDRITE PARENT BODY; T. E. Bunch, NASA-Ames Research Center, Moffett Field, CA 94035

Constituent minerals in howardite clasts, previously investigated for bulk composition,[(1,2)] have been analyzed by the electron microprobe. These minerals consist of pyroxenes, plagioclase, metal, ilmenite, and chromite, in addition to selected mineral clasts of pyroxene. Pyroxene compositions range from bronzite (diogenite mineral clasts) to hypersthene with exsolved augite || to (001) in mafic clasts to ferroaugite and ferrohypersthene with exsolved augite or ferroaugite in basaltic clasts (Fig. 1). The exsolved Ca-rich pyroxene in all cases is enriched in Al, Cr, and Ti, and depleted in Mn relative to the host. This increasing Fe-enrichment in pyroxenes together with increasing Fe/Mg ratios of the host rocks is typical of magmatic differentiation. Plagioclase in mafic clasts is the most calcic (Fig. 2) and contains detectable MgO (0.02-0.05 wt %). Iron content is positively correlated with Ab content in analyzed plagioclase of all rocks. Ilmenite compositions are essentially TiO_2 (49.7-52.7 wt %) and FeO (43.2-46.8 wt %) with minor MnO and MgO. Al-rich clast ilmenite contains small amounts of Al_2O_3 (0.14-0.57 wt %), which suggests partitioning of Al into ilmenite in association with a high Al environment and supports an earlier premise that plagioclase-rich rocks separated from eucritic parental magmas.[(2)] Metal grains in howarditic and eucritic meteorites are difficult to distinguish from lunar metal in terms of Fe-Ni-Co contents.[(3-5)] Metal grains included within howardite basaltic igneous clasts and in eucrites are typically low in Ni (<2.0 wt %) and Co (<0.8 wt %) and probably reflect low concentrations in these highly differentiated rocks. In contrast, metal in bronzite and hypersthene are significantly higher in Co (2.6-3.2 wt %) and slightly higher in Ni (2.0-3.4 wt %). Textural criteria clearly establish an indigenous origin for all of these metal grains and the Ni-Co concentrations are negatively correlated with increasing bulk Fe/Mg ratios. Metal grains within the matrix of howardites are essentially of two types: (1) Grains that are similar to iron meteorite compositions (Ni = 5.0-8.5 wt %; Co = 0.3-0.5 wt %; P = 0.05-0.2 wt %) and are probably remnants of iron meteorites that impacted with the parent body. This metal is also found in shock melt clasts. (2) A much larger group in abundance contains in addition to Fe, Co (0.3-2.0 wt %) and Ni (2.0-5.0 wt %), which is inversely proportional to Co. None of these metal grains are similar to the indigenous types and no solution is offered for their formation. They are similar in composition to metal in Type III carbonaceous chondrites.[(6)]

The indicated mineral fractionation trends imply a common origin through magmatic differentiation for all of the major clast types observed in howardites, in addition to other related meteorites. Mineral and igneous clast compositions in howardites, together with bulk chemistry of eucrites, diogenites, and other related minor meteorites can be modeled to indicate the initial composition of a parent magma. A calculated parental magma consisting of normative Hy (61%), Ol (16%), Di (6%), An (14%), Ab (1%), and Cm and

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Il (2%) would separate out olivine, chromite, and Ni-Fe initially, which is consistent with the observations that the differentiated rocks are depleted in these components. The cumulate meteoritic dunite, Chassigny, may be akin to this hypothetical rock, although Chassigny is more Fe- and alkali-rich than would be expected. Pallasites may also be a candidate, but the existence of so much metal is difficult to reconcile. Continued crystallization of the hypothetical magma could yield the sequence shown in Fig. 3 with the end product being eucrites. This model has not taken into account trace element and REE abundances, but does follow the suggestion of McCarthy, et al.[7] that a parental magma which produced the diogenites and eucrites must be more mafic than Binda. The model offered here is not a unique solution, but is compatible with observed chemical and textural data.

References

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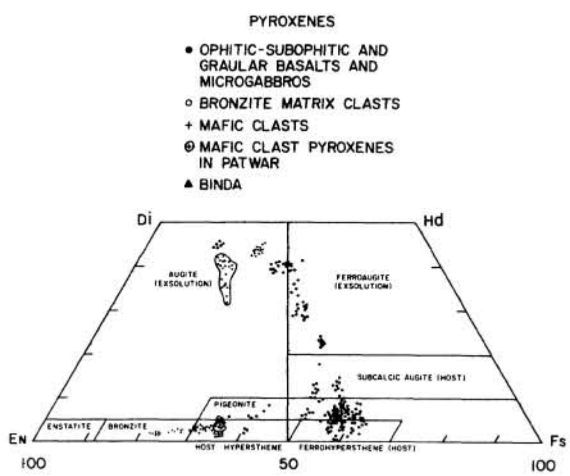

Fig. 1. Pyroxene compositions of mineral and rock clasts in howardites, Patwar mafic clast, and Binda.

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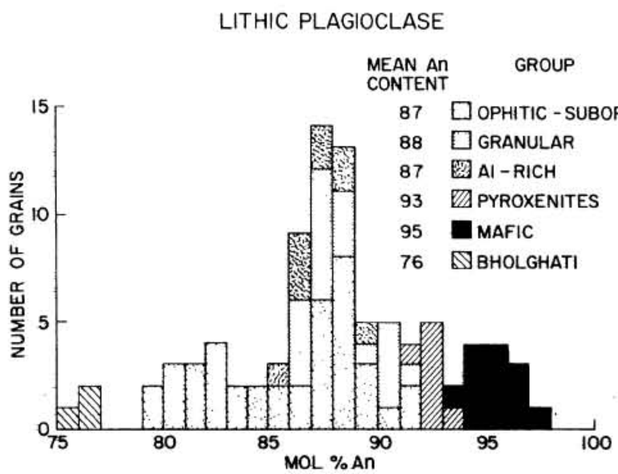

Fig. 2. Plagioclase compositions of howardite igneous clasts. Pyroxenites = diogenites.

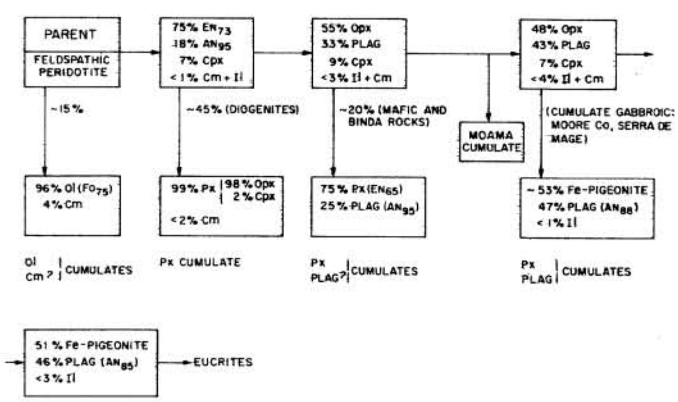

Fig. 3. Hypothetical differentiation sequence for howardite igneous clasts, eucrites, and related rocks.