IMPACT-INDUCED METAL-SILICATE MELT PARTITIONING: FIRST RESULTS FOR BASALT

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We have recovered fragments of shocked samples from equation of state measurements of molten basalt via shock wave experiments. The post-shock remnants consist of pieces of the molybdenum container with basalt glass. Analysis of the glass shows extreme depletion of FeO (Table) from the initial glass composition, with the subsequent formation of Fe-Mo-rich spherules throughout the glass. These results demonstrate the high mobility of siderophile components in the basaltic liquid under high pressure (0.5 - 2.6 GPa) and temperature ($> 2000^oC$) conditions on very short timescales ($\approx 2 - 5\mu s$). The data are preliminary, but provide insight on the chemical constraints for planetary differentiation and core formation.

Our experiments are described in detail by Rigden et al. [1]. Briefly, the sample is encapsulated in a molybdenum container (Figure 1) and heated by induction just prior to shocking. The back surface of the Mo container acts as a driver for the shock wave which is produced by impact of the projectile (an Al metal disk) with the target. The entire experiment lasts a few microseconds and most impacts leave no recognizable traces of the sample. However, for shot 760, a fragment (2.0×1.25 cm) of Mo metal with a thin veneer (≈ 0.2 mm thick) of black basalt glass on its surface was recovered (Figure 2). A detailed chemical analysis of the post-shock basalt glass was done on the electron microprobe. The table shows the differences in composition of the basalt glass (MORB from the Juan de Fuca Ridge) versus the shocked glass. The shocked glass is depleted in FeO, slightly depleted in CaO, MgO and TiO_2 and enriched in SiO_2, Al_2O_3 and Na_2O. Overall, the shocked basalt glass was relatively uniform in composition, with inhomogeneous regions in about 5% of the glass (Figure 2). We divided these regions into three groups based on their composition and morphology: 1. White Mo-Fe-rich spherules ($\approx 4\%$) which ranged in diameter from $40\mu m$ to $< 1\mu m$, 2. Gray spherules, ($\approx 0.5\%$) with diameters of $< 5\mu m$, 3. Gray fibers ($\approx 0.5\%$) which ranged in length from 50 μm to $< 5\mu m$. Several of the spheres and a few of the fibers were semi-quantitatively analyzed on the scanning electron microprobe. A representative chemical analysis for one point from each group is also listed in the table. We have now developed a recovery system for molten silicate EOS experiments and we have recovered pieces of the Mo container and sample from four shots.

The only known basaltic impact glasses on the earth from Lonar Crater, India show only minor depletions of volatile elements (i.e. Na_2O & K_2O) versus the initial Deccan basalts [2]. This suggests that the significant variations we see in our shocked glasses are due to the interaction of the silicate melt with the Mo metal. Mo is on the boundary between a moderate to a highly siderophile element. It is also refractory so it is unlikely to volatilize during impact. These properties allow the Mo to strongly and rapidly leach the Fe component from the basalt melt and form the Mo-Fe-rich spherules. Our data supports the model for the formation of the earth's core by the segregation of a molten iron alloy from a silicate mantle, which produces the long recognized partial depletion

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of siderophile elements (e.g. Cr, W, P, Co, Mo, Re) in the mantle relative to chondritic (C1) values [3]. Mo is depleted in the mantle by $\approx 2.0 \times 10^{-2}$ relative to C1 chondrites + Al=2.38% [4]. The Mo-Fe reactions in our experiments show that it would be possible to deplete the earth's mantle of Mo if it interacts with a Fe-alloy melt. Also these results could be relevant to the giant impact theory for the formation of the Moon in that it may explain the even greater depletion of Mo in the Moon's mantle compared to the earth's [5].

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Oxide Wt %	MORB Glass[a]	Shocked Glass[b]	White Spheres[c]	Gray Spheres[c]	Gray Fibers[c]
SiO_2	48.47 ± 0.29	52.73 ± 1.16	0.68	63.87	56.69
TiO_2	1.03 ± 0.01	0.50 ± .02	0.01	0.33	0.01
Al_2O_3	17.70 ± 0.10	23.56 ± 1.05	0.25	6.40	7.05
FeO	8.96 ± 0.05	1.30 ± 0.13	41.07	2.05	4.51
MgO	7.24 ± 0.06	5.50 ± 0.14	0.01	4.92	0.69
CaO	12.52 ± 0.09	10.81 ± 0.32	0.15	7.57	0.60
K_2O	0.10 ± 0.01	0.103 ± 0.002	0.01	0.11	0.15
Na_2O	2.56 ± 0.02	3.63 ± 0.15	0.86	7.36	1.47
MnO	0.16 ± 0.01	0.101 ± 0.005	0.45	0.27	0.39
MoO_3	0.08 ± 0.02	0.59 ± 0.49	55.53	7.06	32.38
TOTAL	98.92 ± 0.42	98.81 ± 0.26	99.28	99.89	103.90

a Mean and standard deviation for 27 points
b Mean and standard deviation for 56 points
c SEM analysis for one point

Figure 1 Cross Section of Mo Container

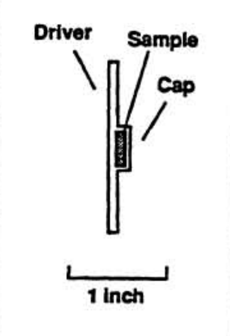
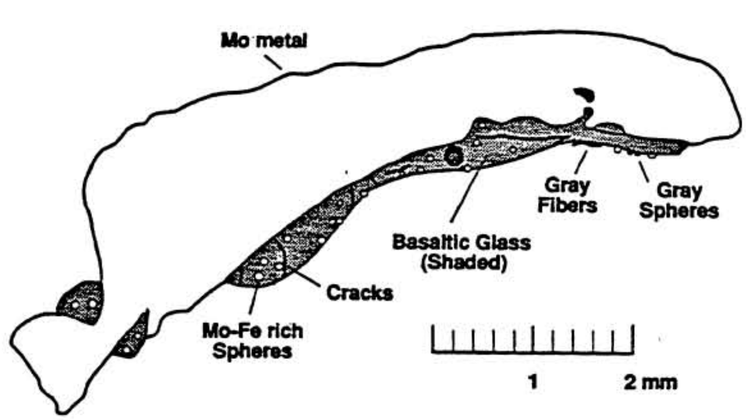


Figure 2

Cross Section of Piece of Recovered Fragment From Shot # 760



MONOGENIC AND POLYGENIC SILICATE CLASTS FROM MESOSIDERITES: IMPLICATIONS FOR ENDOGENOUS IGNEOUS PROCESSES.

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Mesosiderites are complex meteorite breccias consisting of roughly 50% basaltic, gabbroic and ultramafic silicates and 50% metallic Fe-Ni and troilite. Since 1979, 55 igneous silicate clasts from mesosiderites have been analyzed by both neutron activation and electron microprobe [1-8]. Two-thirds of these clasts are polygenic; one-third is monogenic. Polygenic clasts were formed from melts of more than one source (e.g., gabbros derived by melting large portions of a basalt--cumulate-eucrite megaregolith). Monogenic clasts were formed from melts of a single parent lithology (e.g., basalts derived from melting a primary chondritic source).

All of the igneous silicate clasts belong to one of six principal groups: (1) Polygenic cumulates (35%) are coarse-grained (≥800 µm) gabbroic rocks that are highly depleted in incompatible elements relative to H chondrites; they have low La/Lu abundance ratios (typically 0.17-0.44) and extremely high Eu/Sm abundance ratios (typically 45-250). These rocks are much more fractionated than known cumulate eucrites. It seems likely that the polygenic cumulate gabbros were formed at moderate depth either as residues of two or more episodes of low-degree partial melting of pre-existing cumulate eucrites or as cumulates from polygenic melts rich in a cumulate-eucrite component. (2) Polygenic basalts (31%) comprise rocks with textures ranging from subophitic to hypidiomorphic-granular to that of a plagioclase orthocumulate; grain sizes are <800 µm. These rocks all have positive Eu anomalies, La/Lu abundance ratios <1, and lower REE abundances than basaltic eucrites. Their bulk molar MgO/(MgO+FeO) ratios (i.e., mg*) are in the range of basaltic eucrites (~0.33-0.40), but many have pyroxenes with lower Fs contents and lower FeO/MnO ratios (27-34) than basaltic eucrites. Their modal abundances of silica are variable (0.3-9 vol.%) with many being higher than that typical of basaltic eucrites (~4 vol.%). Phosphate abundances are generally low (≤0.2 vol.%), as in basaltic eucrites (~0.1 vol.%). It seems likely that the polygenic basalts were formed near their parent body surface by melting mixtures of major amounts of basaltic eucrites and lesser amounts of cumulate eucrites. (3) Quench-textured rocks comprise two compositional groups: (a) those which resemble basaltic eucrites in bulk composition and have relatively flat REE patterns, high REE abundances and low siderophile concentrations (5%) and (b) those which resemble cumulate eucrites in bulk composition and have moderately high Eu/Sm and Lu/La abundance ratios (5%). The quench-textured rocks are probably monogenic; they most likely formed when small-scale impacts at their parent body surface totally melted basaltic and cumulate eucrites, respectively.

(4) Monogenic basalts (9%) resemble basaltic eucrites and are characterized by subophitic textures, flat REE patterns, higher REE abundances than the polygenic basalts, low concentrations of siderophile and chalcophile elements, mg* in the range of basaltic eucrites, modal abundances of silica and phosphate that are typical of basaltic eucrites, and pyroxene (FeO/MnO ~ 35) that compositionally resembles that of basaltic eucrites. The monogenic basalts formed by endogenous igneous processes on the mesosiderite parent body (MPB) and were not remelted by subsequent meteoroid bombardment. The monogenic basalts and those quench-textured rocks with flat REE patterns plot subparallel to the Nuevo-Laredo-trend eucrites on diagrams of incompatible element concentration vs. mg*. Previous work [9,10] has shown that the Nuevo-Laredo-trend eucrites were probably produced by fractional crystallization. It seems likely that the monogenic basalts from the MPB had a similar origin. (5) Monogenic cumulates (4%) resemble cumulate eucrites and are characterized by gabbroic to granular textures, moderately low REE abundances and moderately high Eu/Sm abundance ratios (~13). These rocks were probably also formed by endogenous magmatic processes. (6) Ultramafic rocks (11%) are cumulates consisting either of large orthopyroxene or olivine crystals. The orthopyroxene crystals resemble diogenites and were most likely formed by endogenous igneous processes. The olivine crystals show a relatively wide range of major element compositions; some may be endogenous, but others may have been derived from the disrupted mantle of a different parent body [11].

The monogenic basalts, monogenic cumulates and orthopyroxenites are similar to HED (howardite-eucrite-diogenite) lithologies; they probably represent the products of endogenous igneous processes on the MPB and pre-date metal-silicate mixing. In contrast, polygenic basalts and polygenic cumulate gabbros were formed after the primary igneous differentiation of the MPB, either during or after metal-silicate mixing. The most plausible heat source responsible for forming the polygenic lithologies is meteoroid bombardment.

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