SHOCK RECOVERY EXPERIMENTS ON MESOSIDERITE ANALOGS

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The origin of silicate-metal textures in mesosiderites is a continuing source of disagreement. Early work recognized that the metal-silicate textures, particularly the rounded and embayed contacts between metal and silicate, and invasion of metal into narrow cracks in the silicates, suggested that molten metal was mixed into a silicate breccia (1,2). Nonetheless, Powell (2) advocated that the metal and silicate were mixed as solids because he felt that molten metal would cause pervasive melting of the silicates, which he did not observe. A recently proposed solid mixing-model suggests sintering at subsolidus temperatures as a mechanism to produce the observed textures (3). Other workers (4) have favored mixing the metal as a liquid in order to satisfy the textural arguments first laid out by Powell (1,2). It appears that the brecciated nature of the metal-silicate mixtures in mesosiderites, including evidence for multiple breccia generations, differential melting of distinct phases, and injection of melts into fine cracks (2) are all compatible with cratering and shock processes. We have therefore undertaken shock recovery experiments on mixtures of silicates and metal as analogs of mesosiderites to characterize the textural and compositional effects with increasing shock stress. We report here the preliminary results of these experiments and compare them with petrologic observations of mesosiderites.

EXPERIMENTAL. Approximately equal weights of Bushveld gabbro (5) and stainless steel 304 (SS 304), each ground and sieved to 75-150 microns, were mixed and loaded in sample holders. Depending on the desired shock stress, the holders were made of aluminum ($\leq$10 GPa shots), SS 304 (10-60 GPa), and fansteel (tungsten alloy) ($\geq$60 GPa shots). Details of sample preparation, actual shock loading by means of a 20 mm powder-propellant gun, sample-recovery procedures, and determination of peak shock pressures are described in (5). Experiments were performed at 5.6, 8.0, 10.0, 25.2, 40.3, 53.0, 68.8 and 77.0 GPa to cover the expected range of predominantly solid-state deformations (<20 GPa) to pervasive melt production (>60 GPa).

TEXTURAL OBSERVATIONS. The samples shocked to 5.2 and 8.0 GPa do not display textures like those in mesosiderites, but sample recovery was poor (inadvertently) and our observations relate to a few small chips only. Both silicate and metal grains remain angular and seem little modified at these levels of shock stress. The 10.0 GPa experiments resulted, however, in textures that are reminiscent of mesosiderites: the sample is well lithified and no void space remained. Incipient melting of both silicate and metal grains is observed along grain boundaries as expected for particulate materials (e.g. 6). These local melts wet and bond neighboring grains. Some metal melts form ~10 micron metal spheres and some occurs as "sponge" metal which contains abundant $\leq$10 micron droplets of silicate melt. Some veins of metal, a few microns thick, transect fractured mineral grains. By and large, however, melts are not common and the target is still largely crystalline. Plagioclase acquired strong undulatory extinction, and most pyroxene is heavily fractured. With increasing pressure, the modal amount of silicate and metal melts increases, but textural relations remain largely as described for the 10.0 GPa experiment. Crystalline plagioclase is dramatically reduced in the 25.2 GPa experiment, where it has been converted to maskelynite (or melt at higher pressures). Crystalline pyroxene, albeit highly fractured, persists even in the 77.0 GPa experiment.

METAL COMPOSITIONS. Preliminary electron microprobe analyses have been conducted, but only for the metallic fractions of the 10.0, 40.3 and 68.8 GPa experiments. In all three of these targets, large, angular metal grains that appear unmelted are identical in composition to unshocked SS 304. However, isolated ~10 micron metal droplets/spheres and the "sponge" metal are fractionated relative to the initial starting material. The metal melts in the 10.0 GPa target are substantially derived from the Al sample jacket judging from their high Al content (20-40%) compared to unshocked SS 304 (<0.2%). The 40.3 and 68.8 experiments were jacketed in SS 304, and fractionation trends therefore apply to shock-molten and disseminated SS 304. Relative to Fe, the melted steel shows depletions in Cr, Mn, Ni and Cu and enrichments in Co and perhaps Si. (Secondary fluorescence from the silicate fraction may explain the Si enrichment in the small melted metal grains.) The element depletions in the most fractionated metal spheres are correlated with the boiling points of the elements (Fig. 1), although the correlation coefficients are not exceptionally good (best correlation $r^2 = 0.836$). This suggests that, to a first approximation, much of the depletion may have been caused by volatilization of metal (6). We cannot address the suggestion that oxidation of metal results in the observed depletion pattern (6) at present, but future microprobe analyses of the silicate melt should permit evaluation of this possibility.

COMPARISON WITH MESOSIDERITES. Many of the textural features we observe in the experimental charges resemble those of mesosiderites, especially the type 1A members. The silicates in the 10.0 GPa shot are a mixture of relict, deformed grains with interstitial shock produced glass. In mesosiderites, fine-grained impact melt enclosing, or interstitial to mineral and lithic clasts is common, even in type 1A mesosiderites. Large metal clasts in mesosiderites sometimes are rich in small silicate inclusions (for examples, see Fig. 2 of (2)), and are similar to the "sponge" metal produced in all of our experiments above 10.0 GPa. We have produced thin metal veins that transect relatively undeformed silicates at shock pressures as low as 10.0 GPa, but these melts may be enriched in Al, and therefore have a low melting temperature.

However, differences in detail do exist. Undeformed, coarse-grained plagioclase is common in mesosiderites from chemical group A. In our 10.0 GPa shock, most plagioclase exhibits shock deformation. At lower shock pressures where plagioclase is less deformed, the metal-silicate textures are much less modified and do not appear to resemble mesosiderites. Note that mesosiderites show petrologic evidence for multiple impact events (2), which we cannot duplicate in our experiments.

REFERENCES. (1) Powell (1969) *Geochim. Cosmochim. Acta 33, 789-810.* (2) Powell (1971) *Geochim. Cosmochim. Acta 35, 5-34.* (3) Jones (1983) *Lunar Planet. Sci. XIV, 351-352.* (4) Delaney et al. (1981) *Proc. Lunar Planet. Sci. 12, 1315-1342.* (5) Hörz et al. (1984) *Proc. Lunar Planet. Sci. Conf. 15th, JGR 89, C183-C196.* (6) Gibbons et al. (1975) *Proc. Lunar Sci. Conf. 6th, 3143-3171.*

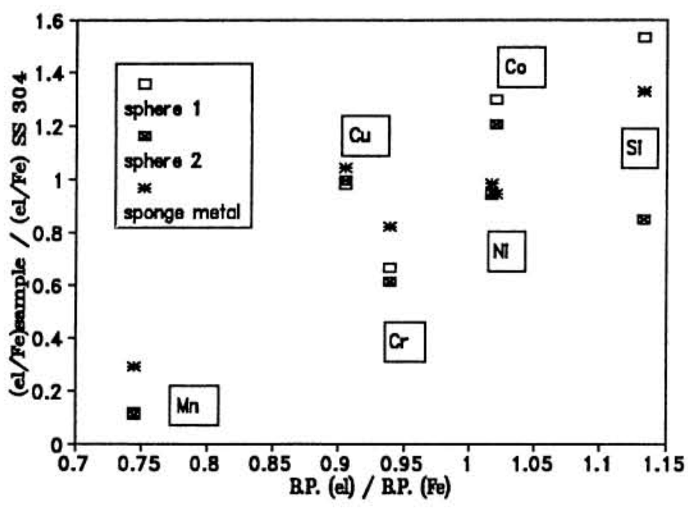

Fig. 1 Correlation of element depletions with boiling point for 2 ~10 micron metal spheres and "sponge" metal from the 40.3 GPa target.