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CAT MOUNTAIN: A METEORITIC SAMPLE OF AN IMPACT-MELTED CHONDRITIC ASTEROID

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Although impact cratering and collisional disruption are the dominant geologic processes affecting asteroids, samples of impact melt breccias comprise <1% of ordinary chondritic material and none exist among enstatite and carbonaceous chondrite groups [1]. Because the average collisional velocity among asteroids is sufficiently large to produce impact melts [*e.g.*, 2], this paucity of impact-melted material is generally believed to be a sampling bias, making it difficult to determine the evolutionary history of chondritic bodies and how impact processes may have affected the physical properties of asteroids (*e.g.*, their structural integrity and reflectance spectra). To help address these and related issues, the first petrographic description of a new chondritic impact melt breccia sample, tentatively named Cat Mountain, is presented below.

Cat Mountain is a 2.7 kg stone containing large dark gray elliptical chondrule-bearing clasts in a medium dark gray vesicular matrix, with silver metal scattered throughout both areas (Fig. 1). In sawn surfaces (120 cm^2), these phases represent 49% of the stone each, while the remaining 2% consists of smaller vesicular and dark clasts. The larger clasts, ranging in size from 0.8 to at least 7.4 cm, are shocked and partially melted L5 material. They contain barred olivine and radial pyroxene chondrules and ghosts of porphyritic chondrules. Olivine (Fo_{75}) and pyroxene ($Wo_1En_{77}Fs_{21}$) are equilibrated and accompanied by lesser amounts of augite ($Wo_{44}En_{47}Fs_8$), chromite (Mg/(Mg+Fe) = 0.16, Cr/(Cr+Al) = 0.86), apatite, whitlockite, martensite, kamacite (0.86 wt.% Co), and troilite. Feldspathic material associated with olivine and pyroxene is either turbid or birefringent and contains spindly to radiating feldspar.

These clasts are crosscut by isotropic polycrystalline dikes of micron-sized silicate phases which are thoroughly mixed with similarly-sized opaque phases (Fig. 2). These dikes often surround unmelted islands or rafts of birefringent (but sometimes recrystallized) olivine and pyroxene. Melt pockets are common at the junctions of multiple dikes. Opaque metal-sulfide veins also crosscut the clasts and sometimes occur along the margins of silicate-rich dikes. While most opaque veins are devoid of silicates, one of them contains small pockets of quenched feldspar laths and skeletal pyroxene crystals. Olivine grains adjacent to the dikes and veins have been variously deformed; they have undulatory extinction, irregular fractures, multiple planar

Fig. 1. Sawn face of Cat Mountain which consists of elliptical L5 clasts in an igneous-textured matrix. The white specks in both the clasts and the melt matrix are Fe,Ni-metal alloys. The width of the stone is ~11 cm.

Fig. 2. Transmitted-light image of a clast in thin-section. Dark polycrystalline dikes and opaque veins crosscut a large portion of the clast. The width of this slice of the clast is 1.8 cm.

fractures, Fe,Ni-metal and sulfide fillings in fractures, and some have been recrystallized. Other deformation features include fractured pyroxene and disrupted chromite, both of which also have Fe,Ni-metal and sulfide fillings.

In contrast to the partially-melted shock-metamorphosed clasts, the matrix is a total melt with a relatively uncomplicated igneous texture. The silicate portion consists of subhedral to euhedral olivine (Fo_{75}), subhedral pyroxene laths ($Wo_2En_{78}Fs_{20}$), some of which poikilitically enclose olivine chadacrysts, and an interstitial feldspathic mesostasis (CIPW normative composition of 48% quartz, 38% feldspar, 11% corundum, 1% hypersthene, 1% ilmenite, and 1% apatite.). A few pyroxene laths have thin (calcic?) rims. One bronzite overgrowth was seen surrounding a partially resorbed relict pyroxene grain; both have similar major element compositions, although the overgrowth contains more Cr_2O_3 (0.95 *vs.* 0.11 wt.%) and less TiO_2 (0.04 *vs.* 0.19 wt.%). The melt assemblage is very fine-grained, typically <50 μm in size, although olivine sometimes nucleated or aggregated into submillimeter-sized polycrystalline clots, producing a fine-grained glomeroporphyritic texture.

The opaque portion of the melt is dominated by Fe,Ni-metal and sulfides, although it also includes chromite (Mg/(Mg+Fe) = 0.18, Cr/(Cr+Al) = 0.86). Some of the metal and sulfide occur in large millimeter- to centimeter-sized distended particles which produce a sense of flow in hand-specimens. Metal-sulfide assemblages are often associated with vesicles, suggesting that sulfur was being volatilized or, alternatively, that the gas vesicles, trapped in a rapidly solidifying silicate melt, associated themselves with more plastic metal-sulfide assemblages. The metal is dominantly martensite (8.8 to 19.3 wt.% Ni) and occurs in ellipsoidal orbs that are embedded in troilite. Thin rims of kamacite (7.1 wt.% Ni), associated with small phosphide patches (probably schreibersite), have crystallized at the interface between the martensite and troilite. Occasional skeletal laths have also crystallized inside the martensitic orbs. Troilite, in addition to being associated with the orbicular metal assemblages, is finely-disseminated in some areas of the melt.

Because the melt fraction of Cat Mountain appears to be total melt and mixed with shock-metamorphosed clasts, it was probably produced by impact processes and is not a plutonic intrusion of melt into a chondritic crust or a volcanic extrusion with crustal xenoliths. To produce the partial and total melts in Cat Mountain, the impact event must have been sufficiently energetic to produce peak temperatures in excess of 1000 °C. As indicated by the vesicles in the melt matrix, these temperatures allowed the breccia to begin degassing. The hot melt was rapidly cooled against the relatively cold clastic material, producing zones of cryptocrystalline (and sometimes isotropic) assemblage of silicates and metal-sulfide droplets around the margins of the clasts. The cooling induced by the rapid thermal equilibration of the clasts and melt, as well as conduction to the melt breccia's surroundings, also quenched the cores in metal-sulfide assemblages to martensite, producing a texture similar to that in Ramsdorf, Rose City, and Orvinio [3,4,5]. However, since the metal orbs in Cat Mountain, like those in Rose City, also have kamacite rims, Cat Mountain probably cooled at a slower rate than Ramsdorf and Orvinio [5], and most likely represents a melt breccia lens or melt dike that was partially insulated by the overburden of fragmental and fallback breccias inside or near the rim of an impact crater.

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References: [1] Scott E.R.D., Taylor G.J., Newsom H.E., Herbert F., Zolensky M., and Kerridge J.F. (1989) in Asteroids II, R.P. Binzel, T. Gehrels, and M.S. Matthews (eds.), University of Arizona Press, Tucson, 701-739. [2] Vickery A.M. and Melosh H.J. (1983) Icarus 56, 299-318. [3] Begemann F. and Wlotzka F. (1969) Geochim. Cosmochim. Acta 33, 1351-1370. [4] Taylor G.J. and Heymann D. (1971) J. Geophys. Res. 76, 1879-1893. [5] Smith B.A. and Goldstein J.I. (1977) Geochim. Cosmochim. Acta 41, 1061-1072.