A PYROXENE-ENRICHED SHOCK MELT DIKE IN THE BUCK MOUNTAINS 005 (L6) CHONDRITE.

M. Hutson (mhutson@pdx.edu)[1], A. Ruzicka[1] and R. Brown[1], [1]Cascadia Meteorite Laboratory, Department of Geology, Portland State University, 1721 SW Broadway, Portland OR 97207.

Introduction: The Buck Mountains 005 (L6 S4 W2) chondrite contains a remarkable ~3-mm-wide complexly-zoned dike that was obviously produced by shock [1]. The chemistry, mineralogy and texture of the dike indicate that it formed by various processes, including melting accompanying cataclasis, partial loss of metal and sulfide, partial vaporization, FeO reduction of melt, recrystallization of entrained clasts, and rapid solidification. The net result of these processes was to transform starting L chondrite into a more pyroxenitic, igneous lithology.

Dike Structure: The dike is dominantly fine-grained (grains <10-15 µm across) and has a core-rim structure (Fig. 1). The inner dike contains larger clasts (~50-400 µm across) of olivine and pyroxene that sometimes are recrystallized, whereas the outer dike is dominantly fine-grained and has grain size decreasing towards the host. Clasts occupy ~25 area% of the inner dike and ~6 % of the outer dike. A band of troilite and cellular metal (largely but not completely altered by terrestrial weathering) entraining angular silicate clasts and crystals is concentrated at the edges of the inner dike. The outer dike contains globules with cellular or dendritic texture that are concentrated towards the host. Thin shock veins in the host are subparallel to the dike, and one thicker vein branches from the dike into the host (Fig. 1). High pressure mineral phases were not observed, although maskelynite is present in the host close to the dike and the branching vein.

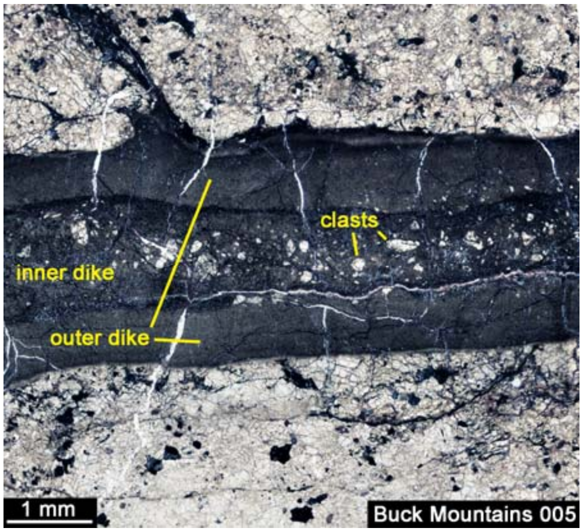

Fig. 1. Transmitted light image showing a portion of the dike and adjacent L6 chondrite host.

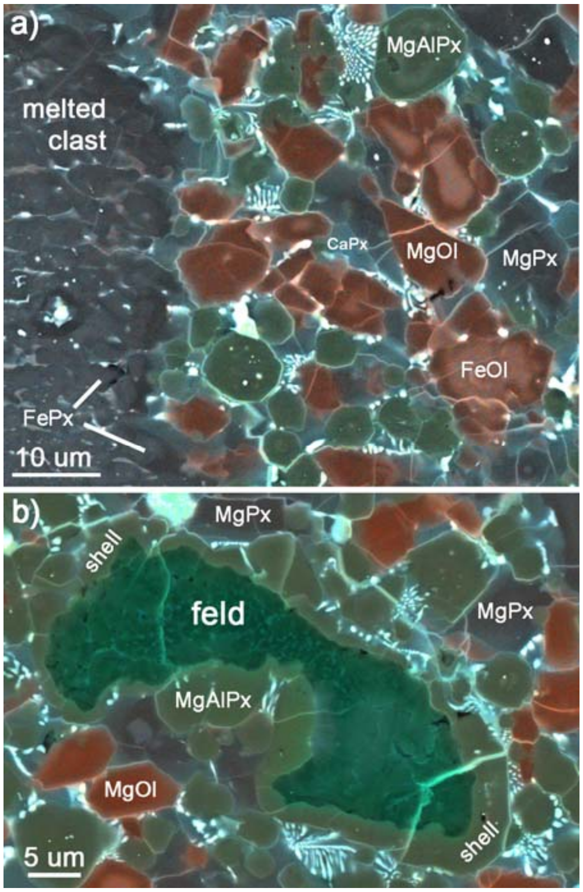

Fig. 2. Closeup SEM images of the dike colorized according to composition (dark red = Mg-olivine, light red = Fe-olivine, olive-green = MgAl-pyroxene, dark grey-purple = Mg-pyroxene, light grey = Fe-pyroxene, dark green = feldspar; white to light blue = weathered metal. a) Dike groundmass (right) and a melted and re-solidified clast (left). b) Rare feldspar patch, surrounded by MgAl-pyroxene shell.

Dike Mineralogy, Mineral Chemistry and Texture: The dike is holocrystalline and dominated by groundmass ferromagnesian minerals that are more magnesian than the host, and which obviously crystallized from melt. This includes euhedral-subhedral Mg-olivine (Fa_{11-25}, mean Fa_{15}), euhedral-subhedral Mg-Al-pyroxene ($Wo_{2.5-6.6}$ Fs_{12-22}, mean Fs_{15}), and anhedral Mg-pyroxene (Wo_{1-19} Fs_{10-31}, mean Fs_{16}) (Fig. 2). Mg-Al-pyroxene typically contains ~6-9 wt% Al_2O_3 and has up to ~14 wt% alumina (Fig. 3). Mg-pyroxene shows prominent igneous core-rim zoning and is zoned to pigeonite in the rims (Fig. 3). This pyroxene tends to be interstitial to the Mg-Al-pyroxene and olivine (Fig. 2) and must have crystallized relatively late.

Ferroan olivine (Fa_{18-27}, mean Fa_{24}) and ferroan low-Ca pyroxene ($Wo_{0.7-4.5}$ Fs_{15-25}, mean Fs_{19}) grains are present in the dike and are rimmed by Mg-olivine and Mg-pyroxene, respectively (Fig. 2). Ferroan grains with compositions similar to the host are present as larger clasts and formed by simple cataclasis. Other ferroan olivine and pyroxene grains are more magnesian, and sometimes show textures indicative of solidification from a melt (Fig. 2a). These ferroan grains are probably relict grains or clasts that were melted, but which resolidified without fully equilibrating with the surrounding melt.

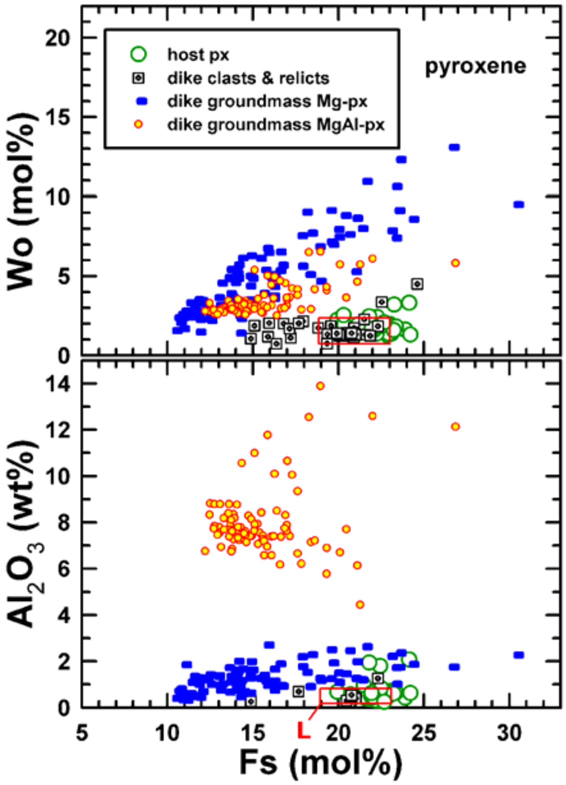

Fig. 3. Pyroxene compositions. The red box shows compositions typical of equilibrated L chondrites [2].

Feldspar is notably depleted in the dike, comprising only ~1.9 area% of the inner dike and <0.1 % of the outer dike. Dike feldspar occurs as isolated, somewhat irregular forms (Fig. 2b). This feldspar has a composition ($Ab_{84\pm3}$ $Or_{5\pm3}$) similar to that of the host ($Ab_{83\pm2}$ $Or_{6\pm1}$). The form and composition of the feldspar suggest that this feldspar was incorporated as clasts. Such feldspar is always surrounded by shells of Mg-Al-pyroxene (Fig. 2b). This shell pyroxene has the highest alumina contents (>9 wt%) of all dike pyroxene (Fig. 3). The shells clearly represent reaction products, and likely were produced by crystallization of Mg-Al-pyroxene from melt that was enriched in alumina by the partial dissolution of feldspar.

A striking feature is the presence of fine-grained metal symplectite that tends to occur interstitial to silicates (Fig. 2). These symplectites (now terrestrially weathered) are essentially free of Ni, unlike the metal in intergrowths with troilite. The symplectite metal almost certainly formed by FeO reduction, which would explain their Ni-free composition. The symplectites are present in an igneous groundmass, so they probably crystallized from silicate melt that was undergoing FeO reduction.

Bulk Chemistry: Modal reconstruction was used to calculate a bulk composition. The dike has chondritic abundances of Al, Ca, Mg, Si, and Cr, but is progressively depleted in Mn, Na, and K, suggesting loss of volatile elements during vaporization. The inner and especially outer dike are depleted in Fe, Ni, and S, suggesting partial loss of a metal-sulfide melt.

Discussion: The mineralogy of the dike differs from L chondrite in some important ways. The very low content of feldspar, presence of highly aluminous pyroxene, and presence of Al-pyroxene shells around feldspar clasts clearly indicate the breakdown of feldspar to form Al-pyroxene. Partial vaporization of alkalis would have destabilized feldspar and left excess Al and Si that could have been incorporated into pyroxene. Moreover, the olivine/(olivine+pyroxene) area (or volume) ratio in the dike (~0.28 in the inner dike and only ~0.22 in the outer dike) is much lower than in L chondrite (>0.6), indicating excess pyroxene relative to olivine. This change can be partly ascribed to the formation of pyroxene by the breakdown of feldspar, as described above, but also can be ascribed to FeO reduction, which would tend to destabilize olivine and form pyroxene instead. Thus, vaporization and FeO reduction, acting together, both contributed to creating a more pyroxenitic lithology. The relatively low proportion of clasts and the volatile-element depletion indicates that temperatures in the shock melt were high initially, sufficient to largely melt and partly vaporize the starting chondrite. However, subsequent cooling must have been rapid, to prevent the complete destruction of entrained clasts and relict grains, to form narrow rims on these materials, and to produce cellular-dendritic metal-sulfide. Still, rapid cooling did not prevent full crystallization.

References: [1] Hutson M., Ruzicka A., Jull A.J.T., Smaller J.E., and Brown R. (2013) *Meteoritics & Planetary Science*, In Press. [2] Brearley A. and Jones R.H. (1998) *Reviews in Mineralogy, 36*, pp. 3-1 to 3-398.