METALLIC CHONDRULES IN NWA1390 (H3-6): CLUES TO THEIR HISTORY FROM METALLIC CU. A. R. LaBlue and D. S. Lauretta, Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721, USA. lauretta@lpl.arizona.edu.

Introduction: A recent study of ordinary chondrites suggests that many long-recognized shock indicators in olivine and pyroxene minerals may be erased by post-shock annealing [1]. Therefore, the presence of other indicators of shock, which can not be erased by subsequent heating, are important to fully characterize the history of chondritic meteorites. One such proposed indicator is metallic Cu, which occurs in at least 2/3 of ordinary chondrites [2,3]. Here we present a comparative study of two metallic chondrules in the NWA1390 ordinary chondrite, both of which contain appreciable Cu in the Fe,Ni metal phase and one that is partially rimmed by metallic Cu.

Analytical Techniques: Thin sections of NWA 1390 were surveyed using optical microscopy and back-scattered electron imaging. Mineral compositions were determined by electron microprobe analysis on the Cameca SX-50 at the U of Az.

Results: We studied the only two metallic chondrules in a single thin section of NWA 1390. Representative mineral compositions are in Table 1. The larger of the two is shown in Figure 1A and has a diameter of 2020 microns. It is composed primarily of kamacite with variable amounts of Zn (up to 0.13 wt.%) and Cu (up to 0.19 wt.%). There are bands of Ni-rich metal with peak Ni contents of 49.5 wt.% Ni. The Ni-rich bands are confined to the interior of the chondrule in a region whose outline appears to have the same shape as the chondrule itself (circular rim with straight bands). In addition to the Ni-rich bands several regions of plessite occur in the chondrule interior. The large chondrule is partially rimmed by schreibersite (Figure 1B), which contains up to 0.2 wt.% Cu. The schreibersite contains inclusions of troilite and kamacite. A partial rim of metallic Cu occurs between the chondrule and an external troilite layer (Figure 1C). Analyses of this material yields ~95 wt% Cu with detectable amounts of Fe, Ni, and S. It is likely that the Fe, Ni, and S are in small sulfide inclusions that occur throughout the Cu and between the Cu and kamacite. Troilite external to the Cu rim contains Ni (0.4 wt.%) and Cu (0.15 wt.%).

The small chondrule, shown in Figure 1D, is 840 microns in diameter. The entire chondrule is composed primarily of kamacite which contains up to 0.1 wt.% Cu and 0.1 wt.% Zn. It has a few Ni-rich metal bands which contain up to 48.4 wt.% Ni. There are several large cracks that extend through the metallic chondrule.

Discussion: NWA1390 is a brecciated meteorite and contains clasts of ordinary chondrite material ranging in petrologic grade from type 3 to type 6. The two objects studied here occur in type-3 clasts that contain abundant, well-defined chondrules. Both objects have spherical morphologies, suggesting solidification from a molten droplet. Kamacite in the two metallic chondrules has similar abundances of Ni, Co, Cu, and Zn. Both contain bands of high-Ni metal in which Ni and Cu exhibit M-shaped profiles bands, indicating separation of the two phases during slow cooling [4]. The Cu distribution pattern mimics that of Ni, indicating that Cu diffuses along with Ni during diffusion-controlled growth processes. The Ni content in the center of bands in both chondrules is ~35 wt.%. However, the bands in the larger chondrule average 25 μm in width while those in the smaller chondrule are ~10 μm across. The larger bandwidths reflect slower cooling.

The most intriguing difference between the two objects is the presence of Cu, phosphide, and sulfide rims on the larger chondrule. Both objects are rimmed by oxides, but these likely resulted from terrestrial weathering. If the Cu rim on the larger chondrule formed by shock, the mechanism suggested by [2], then it would seem that two objects experienced significantly different shock histories.

In NWA 1390, Cu occurs between metal and troilite. Shock processes are known to cause local melting and transportation of Fe-Ni and troilite [2]. Cu is often associated with these phases and if there is enough low-temperature re-heating the Cu will separate from troilite and form a border around them. If shock heating is responsible for the formation of metallic Cu in NWA 1390 then it is likely that the schreibersite rim formed at the same time. In this case, schreibersite may be an additional shock indicator that could survive post-shock annealing. Alternatively, the Cu and phosphide rims may have formed through gas-solid reactions, since Cu and P have similar volatilities.

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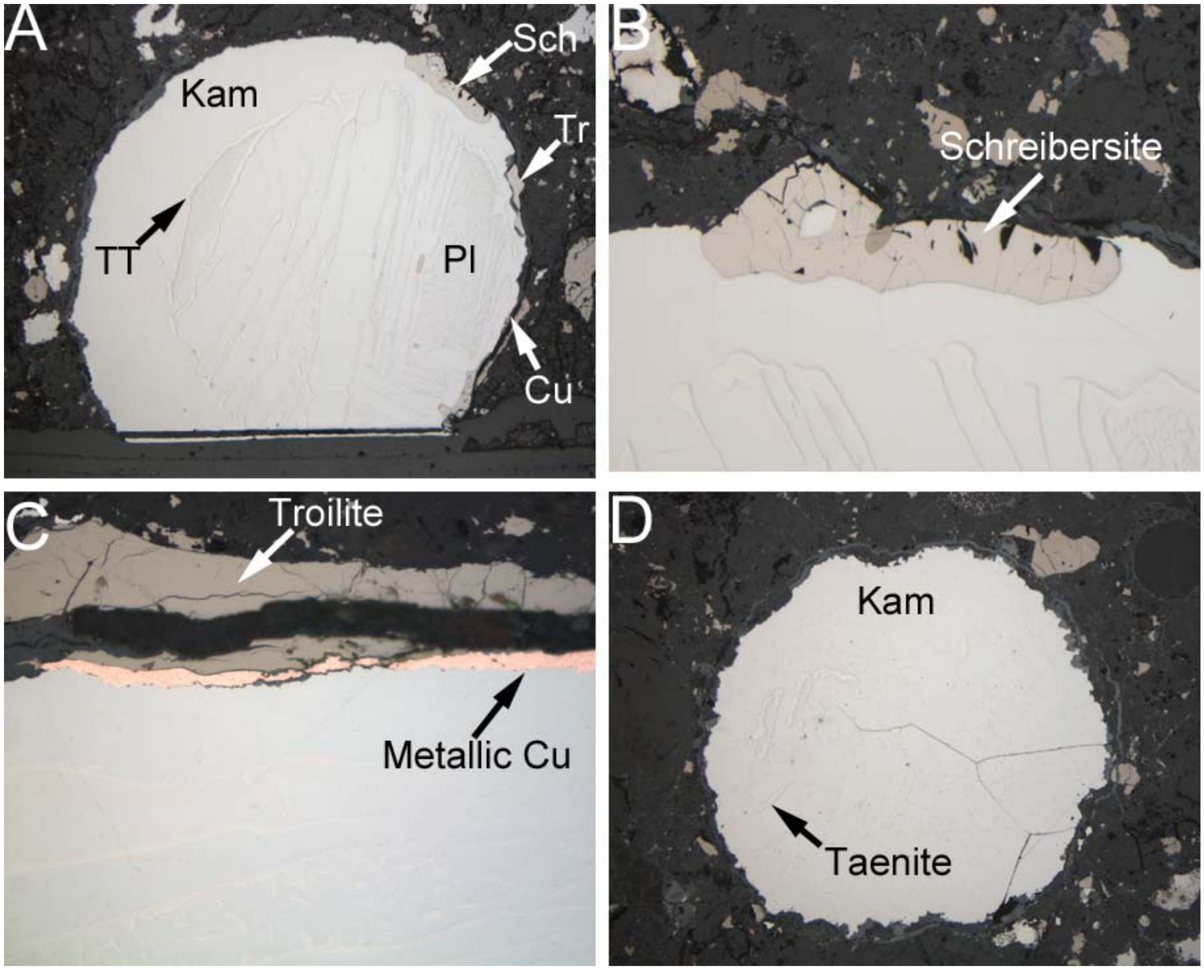

Figure 1. Reflected-light images of the metallic chondrules. **A.** Large metallic chondrule composed of kamacite (Kam) with bands of tetrataenite (TT) and regions of plessite (Pl). Partial rims of schreibersite (Sch), troilite (Tr), and metallic Cu occur. FOV = 2700 µm. **B.** Enlarged view of the schreibersite rim. FOV = 710 µm. **C.** Enlarged view of the Cu rim. FOV = 1350 µm. **D.** The small metallic chondrule. FOV = 1350 µm.

Table 1. Representative Mineral Compositions (wt.%)

Phase	P	S	Fe	Co	Ni	Cu	Zn	Total
Large Metallic Chondrule								
Kamacite	0.04	BDL	93.8	0.41	5.82	BDL	0.13	100.1
Kamacite	0.06	BDL	92.9	0.39	6.49	0.19	BDL	100.0
Taenite	BDL	BDL	64.4	0.09	34.4	0.21	BDL	99.1
Tetrataenite	BDL	BDL	49.5	0.05	49.5	0.30	BDL	99.4
Schreibersite	15.5	BDL	36.4	0.03	47.8	0.10	0.03	99.9
Metallic Cu	0.08	1.33	2.71	BDL	1.22	94.6	BDL	99.9
Troilite	0.02	36.5	62.1	BDL	0.41	0.15	BDL	99.2
Small Metallic Chondrule								
Kamacite	BDL	BDL	93.2	0.42	5.60	BDL	0.09	99.3
Kamacite	BDL	BDL	94.4	0.44	4.94	0.11	BDL	99.8
Tetrataenite	BDL	BDL	48.4	0.03	50.2	0.19	NA	98.9

BDL = below detection limit