

OPAQUE MINERAL ASSEMBLAGES AT CHONDRULE BOUNDARIES IN THE VIGARANO CV CHONDRITE: EVIDENCE FOR GAS-SOLID REACTIONS FOLLOWING CHONDRULE FORMATION.

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Introduction: Recent studies of opaque minerals in primitive ordinary chondrites suggest that metal grains exposed at chondrule boundaries were corroded when volatile elements recondensed after the transient heating event responsible for chondrule formation [1-3]. Metal grains at chondrule boundaries in the Bishunpur (LL3.1) chondrite are rimmed by troilite and fayalite. If these layers formed by gas solid reaction, then the composition of the corrosion products can provide information on the chondrule formation environment. Given the broad similarities among chondrules from different chondrite groups [4], similar scale layers should occur on chondrules in other primitive meteorite groups. Here I report on metal grains at chondrule boundaries in Vigarano (CV3).

Analytical Techniques: A polished thin section of the Vigarano chondrite (sample USNM 6295-2) was surveyed using optical microscopy. Ten candidate chondrules were chosen for further study based on the presence of abundant metal grains in chondrule interiors and boundaries. The compositions of mineral grains in opaque assemblages were determined using the Cameca SX-50 electron microprobe at the U of Az. Two different sets of analytical conditions were used. An accelerating voltage of 15 kV and a beam current of 20 nA was used during the analysis of Si, P, S, Cr, Fe, Co, and Ni. An accelerating voltage of 15 kV with a beam current of 200 nA was used to measure the abundances of Cu, As, Se, and Te. Representative analyses of the different phases are given in Table 1.

Results: The opaque assemblages that occur along the edge of one of the chondrules are shown in Figure 1A and a magnified image of one of the assemblages is shown in Figure 1B. The core of these assemblages is kamacite containing 4.7 to 8.5 wt.% Ni. The abundances of Co, P, and Cr are anti-correlated with Ni. In contrast, the abundances of Cu and As increase with Ni content. Ca- and Fe-rich phosphate occurs between the metal and a troilite rim. The troilite contains appreciable Ni along with detectable amounts of P, Cu, and Se. Tetrataenite occurs as inclusions in the sulfide layer. The tetrataenite contains detectable amounts of Cu and As. Beam overlap with the surrounding sulfide resulted in some S in the analysis. Both the metal and sulfide grains in this assemblage contain multiple, small inclusions of chromite, phosphates, and silica. Large inclusions of Al-rich material are in troilite.

There are distinct differences between the assemblages in the chondrule interior (Figs. 1C and D) and those that occur at the chondrule edge. Kamacite in the

chondrule interior contains less Ni, and more Co, Cr, P, and Si. Chromite inclusions are less abundant. Inclusions of silica and phosphate are not present. Troilite in the chondrule interior occurs as coarse grains together with taenite and magnetite in a droplet morphology. Troilite is absent in some of the interior assemblages.

Discussion: The assemblage shown in Figure 1B has several characteristics that are consistent with alteration of a metal grain, similar to that shown in Figure 1D, by gas-solid reaction. There is a thin band of Ni-enriched metal along the metal-sulfide interface. Nickel-rich blebs of metal occur as inclusions in the sulfide layer. The stoichiometry of the sulfide is nearly ideal (cation-to-sulfur ratio ~1). There is a significant amount of Ni in the sulfide (0.35 wt.%). The sulfide layer is separated from the remnant metal by a small gap. There are multiple cracks that extend from the top of the sulfide layer down to the metal-sulfide interface. A band of P-rich material occurs between the metal and sulfide. All of these characteristics have been observed in experimental studies of Fe-Ni alloy sulfurization [5-7]. The presence of metal grains that have reacted with an atmosphere external to the chondrule allows for quantitative constraints on the gas phases present and the cooling rate after silicate mineral solidification.

Prior studies of labile element release from carbonaceous chondrites have shown that As, Se, and Te are released simultaneously with S from Vigarano at 400 °C under an Ar atmosphere [8]. In the assemblage shown in Figure 1B, As is contained in both kamacite and tetrataenite and Se is present in the sulfide. There is no detectable Te in this assemblage. These observations suggest that the carrier of low-temperature As, Se, and Te is not troilite but another S-bearing phase.

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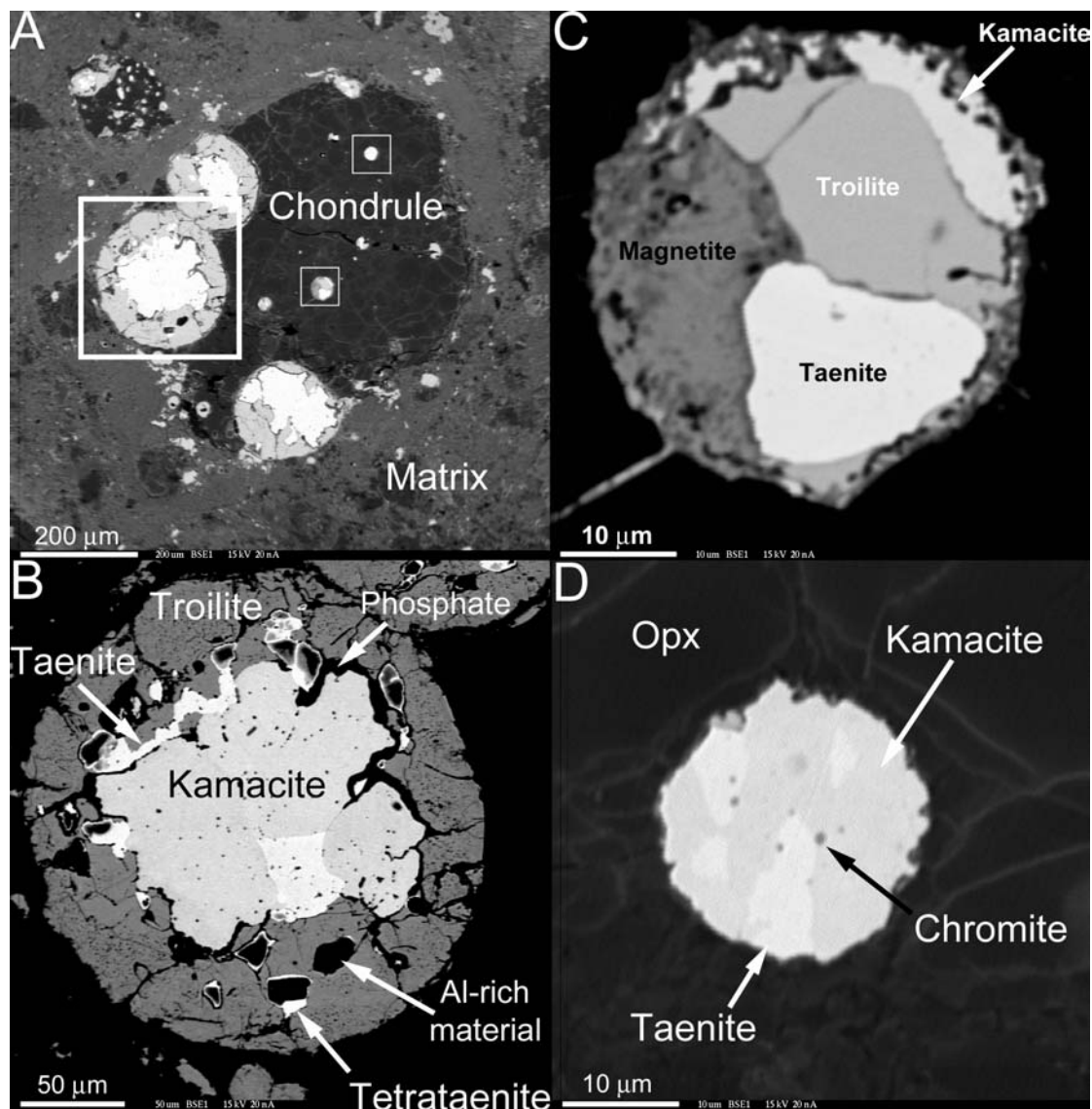


Figure 1 (A) Back-scattered electron image of a type-IB chondrule with several opaque assemblages along its boundary and in the chondrule interior. (B) An opaque assemblage along the chondrule boundary. (C) Multi-phase opaque assemblage in the chondrule interior. (D) Metallic grain in the chondrule interior.

Table 1. Representative Compositions of Opaque Minerals from Assemblage in Fig. 1 (wt.%)

Phase	Si	P	S	Cr	Fe	Co	Ni	Cu	As	Se	Te	Total
Minerals in Chondrule Interior												
Troilite	BDL	BDL	36.7	0.05	64.0	BDL	0.07	BDL	BDL	0.08	BDL	100.9
Kamacite	0.05	0.08	BDL	0.32	94.5	1.06	3.27	BDL	BDL	BDL	BDL	99.3
Taenite	BDL	BDL	BDL	0.08	66.1	0.22	32.8	0.15	BDL	BDL	BDL	99.3
Minerals at Chondrule Boundary												
Troilite	BDL	0.07	36.4	BDL	62.2	BDL	0.35	0.03	BDL	0.06	BDL	99.1
Kamacite	0.03	0.03	BDL	0.14	93.8	0.96	4.73	BDL	BDL	BDL	BDL	99.7
Kamacite	BDL	BDL	BDL	BDL	90.5	0.88	8.45	0.17	0.06	BDL	BDL	100.1
Taenite	BDL	BDL	BDL	0.04	66.3	0.31	32.4	0.14	BDL	BDL	BDL	99.2
Tetrataenite	0.04	0.03	0.46	0.05	44.9	0.04	52.5	0.24	0.06	BDL	BDL	98.3

BDL = below detection limit