**SHOCK MELTING IN IIIE IRON METEORITES – IMPLICATIONS FOR PARENT-BODY HISTORY.**

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**Introduction:** The IIIE irons comprise a small C-rich magmatic group (currently with 15 members) of coarse and medium octahedrites closely related to group IIIAB [1]. The C is commonly found as haxonite ($(Fe,Ni)_{23}C_6$) in plessitic regions. We examined thick sections of nine samples: Aliskerovo (Ali), Armanty (Arm), Cachiyuyal (Cac), Colonia Obrera (CO), Kokstad (Kok), NWA 4704 (4704), Porto Alegre (PA), Rhine Villa (RV) and Willow Creek (WC).

**Petrography:** Five of these meteorites (Arm, CO, 4704, PA, RV) exhibit no significant shock effects: (1) Their plessite regions lack graphite, but many regions contain haxonite; the haxonite grains vary in size from ~15 µm in CO to ~100 µm in Arm. (2) Sulfide grains consist typically of massive troilite (up to 1100 µm in maximum dimension) containing 5-50 vol.% daubréelite ($FeCr_2S_4$) exsolution lamellae (e.g., Fig. 1). In one CO occurrence, a sulfide assemblage is associated with a 215×370-µm-size chromite grain. Some sulfide assemblages in 4704 and PA are partly surrounded by schreibersite; in other cases, small (10-20-µm-size) patches of schreibersite are present at the margins of the sulfide assemblages.

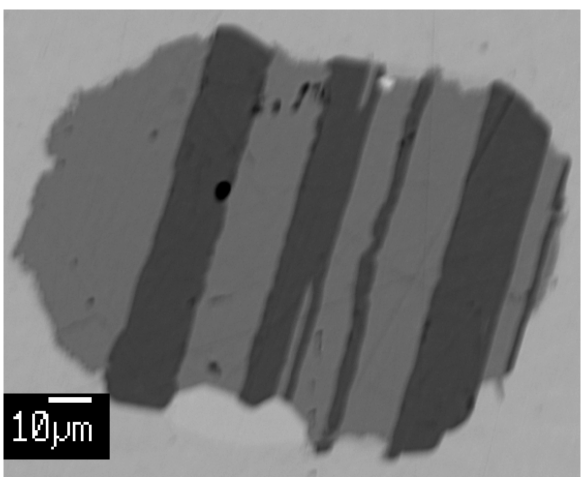


Fig. 1. Unshocked troilite (light gray) grain with daubréelite exsolution lamellae (dark gray) from RV.

The shocked IIIE irons are very different. We found a total of 20 sulfide- and phosphorus-rich melt inclusions in three Ali sections and one WC section (e.g., Fig. 2a,b). Most inclusions are ellipsoidal and are 100-350 µm in size. Typical assemblages consist of (a) 30-50 vol.% subhedral to euhedral daubréelite crystals 10-70 µm in size with thin rims of nonvesicular troilite, (b) 40-70 vol.% anhedral to euhedral grains of low-Ni kamacite (3.1±0.4 wt.% Ni); ~85% of these grains contain 0.52±0.12 wt.% Co, but ~15% are relatively Co rich (1.6±1.0 wt.% Co), (c) 1-5 vol.% irregular 5-10-µm-size grains of tetrataenite (averaging 54.1 wt.% Ni), (d) ~1 vol.% small (10-20-µm) randomly scattered blebs of schreibersite, and (e) 1-4 vol.% elongated 5-10-µm-thick clusters of highly vesicular troilite (with 30-50 vol.% vugs) decorating cracks in the host kamacite. Most of these inclusions are partially surrounded by 10-70-µm-thick bands of schreibersite with 43.6±4.0 wt.% Ni. (In unshocked IIIE irons, schreibersite not associated with daubréelite contains only ~35.0 wt.% Ni.)

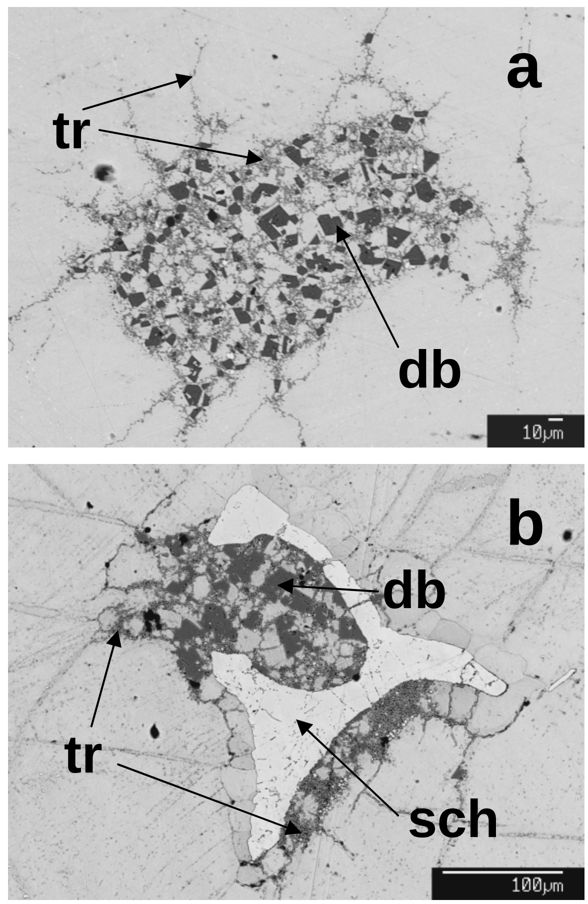


Fig. 2. BSE images of sulfide-rich inclusions (a) Ali-10 and (b) Ali-3. The inclusions contain euhedral daubréelite (db - black), low-Ni kamacite (light gray), thin clusters of vesicular troilite (tr - dark gray), and patches of schreibersite (sch - very light gray).

In the Ali regions distant from the sulfide-rich inclusions, kamacite and schreibersite have normal compositions (6.4±0.4 and 35.7±0.9 wt.% Ni, and 0.49±0.04 and 0.08±0.03 wt.% Co, respectively).

The smallest sulfide-rich inclusions deviate significantly in texture from large inclusions. For example, the two smallest Ali inclusions (separated by only 110 µm) are both 60×70 µm in size. Nearly all of the daubréelite in each inclusion is contained within a single 30×50 µm euhedral grain; these inclusions are especially troilite-poor, containing <1 vol.% FeS. It is possible that these inclusions are connected in the third dimension. The smallest WC inclusion (15×30 µm) contains little daubréelite: only three 5-10-µm-size grains of daubréelite are present in the plane of the section. These grains occur within 80-90-µm-long filaments of troilite that extend outward from the main body of the inclusion. These small, unusual inclusions may actually be the edges of more-typical large inclusions. In fact, examination of the edges of large inclusions in Ali and WC shows that these regions are constituted mainly of filaments of vuggy troilite.

The sole oxide phase we identified in Ali is a large (760×1350 µm) grain of wüstite (with 4.6 wt.% NiO). This grain contains one 20-µm-size kamacite bleb (with 4.9 wt.% Ni and 0.51 wt.% Co) and ~3 vol.% widely dispersed 1-3×10-70-µm-size needles of schreibersite with 50.9±0.5 wt.% Ni. Wüstite is not a common product of terrestrial weathering of meteorites. The kamacite bleb and schreibersite needles within the grain also suggest a preterrestrial origin.

Plessite regions in Ali and WC lack haxonite, but about one third of the plessite regions instead contain quasi-ellipsoidal patches (up to 230×500 µm) rich in elongated grains of graphite (typically 10×50 µm).

Although we identified no sulfide inclusions in our Kok section, Buchwald [2] reported vesicular troilite that resembles that in Ali and WC. He also reported metal textures and graphite in Cac that are consistent with shock. It seems probable that Kok and Cac were shocked to degrees similar to those of Ali and WC.

**Formation:** The sulfide inclusions in Ali and WC must have formed from melts: (1) The quasi-ellipsoidal shapes imply surface-tension effects. (2) The daubréelite grains have subhedral to euhedral morphologies, consistent with crystallization from a liquid. (3) Much of the troilite is highly vesicular, implying loss of S as a volatile phase, presumably $S_2$.

It is likely that the precursor assemblages of Ali and WC resembled the IIIE meteorites that exhibit no shock effects (e.g., CO, 4704, RV). Thus, the melt inclusions in Ali and WC must have formed from already solidified materials, and hence at an epoch when $^{26}$Al contents were negligible. The only plausible heat source that could melt IIIE sulfide-rich inclusions was that due to collisions. Localized impact-heating is indicated because kamacite and schreibersite in regions of Ali and WC distant from the sulfide inclusions have the same compositions as in unshocked IIIE irons.

We infer that, during impact heating, the sulfide assemblages melted, troilite partly vaporized and may have quenched into a glass. The liquid became increasingly rich in Fe and Cr; on cooling, daubréelite crystallized from the melt. Minor amounts of troilite crystallized around the daubréelite. Abundant P in the melt led to the crystallization of schreibersite, in many cases as massive grains (Fig. 2b). Plessite regions in Ali and WC experienced post-shock annealing; haxonite was transformed into graphite.

Like other magmatic iron-meteorite groups, IIIE irons plot on element-element diagrams as narrow quasi-linear bands with slopes consistent with derivation from fractionally crystallized metal cores. Meteorites plotting near each other within these bands have similar bulk compositions and presumably formed relatively close to one another during primary crystallization of the metallic magma. Although Ali, Cac, Kok and WC were all likely impact melted, WC plots far from these other samples on such diagrams. For example, on the Ni-Au diagram (Fig. 3), the unshocked IIIE irons RV and 4704 plot in between Ali and WC. Collisional events appear to have produced heterogeneous shock effects, as is already evident within Ali itself.

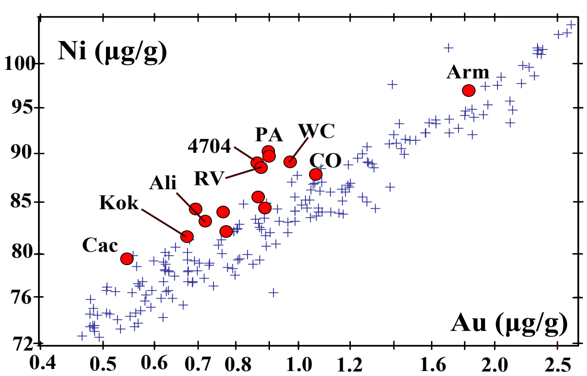


Fig. 3. Ni vs. Au diagram for IIIE irons (large red dots) and the related IIIAB irons (small blue crosses). Both Ni and Au partition into the liquid during crystallization. Among IIIE irons, Cac crystallized early and Arm crystallized late during asteroidal core formation.

**References:** [1] Malvin D. J. et al. (1984) *Geochim. Cosmochim. Acta, 48,* 785-804. [2] Buchwald V. F. (1975) *Handbook of Iron Meteorites*, Univ. Calif. Press, 1418 pp.