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Microstructure of the Muonionalusta Octahedrite Meteorite

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Muonionalusta is a fine octahedrite Fe-Ni meteorite with about 8.42% Ni that landed in Sweden. Its terrestrial age has been estimated as >800,000 years. Four specimens have been found, although the whereabouts of the first specimen, found in the late 19th century is unknown. It is believed to have been part of a massive fall but, due to the bogs and swamps in the landing site, only a small amount has been found.

The second piece weighed 7.53 kg and was found in 1906 by a 10 year old boy tending cattle close to the border with Finland. The third piece weighed 15 kg and was found in 1946 buried in gravel during excavating for a house. The fourth piece weighed 6.2 kg and was found in 1963, also in a gravel pit. Due to the long time on earth, corrosion removed the original fracture surfaces and there has been selective attack along the kamacite α-phase. The length-to-width ratio of the highly elongated kamacite grains is ~40 and the average width is 0.29 ± 0.05 mm. The kamacite has a dense mixture of shocked ε and Neumann bands (mechanical twinning from extraterrestrial collisions). The kamacite hardness is consequently one of the highest of known Fe-Ni meteorites at 335 ± 20 HV. There are subgrain boundaries in the ferrite but they are relatively free of second-phase precipitates. Plessite (a two-phase mixture of kamacite and taenite, i.e., ferrite and austenite) has a volume fraction of about 40% and is mainly of the comb and net types. Some schreibersite, $(Fe,Ni)_3P$, is present, but the amount is low since the phosphorous content is only about 0.05%. Schreibersite is rather brittle and usually exhibits a crack pattern. Troilite, FeS, can be observed in the kamacite, but the amount present is small. Daubreelite, $FeCr_2S_4$, can also be observed in the kamacite as isolated particles generally <30 μm in diameter.

Figure 1 shows examples of a heavy deformation band, unusual in Fe-Ni meteorites, that runs across this specimen, which was relatively free from the affects of terrestrial corrosion. The colored grains are kamacite (ferrite) and they are colored according to their crystallographic orientation. The thin white phase between the kamacite grains is taenite (austenite). There is substantial shock deformation in the kamacite and some Neumann bands. Pleassite is present in both images, but can be seen better in Figure 2. Note the heavy shock deformation in the brown kamacite which also contains many sub-grain boundaries (Fig. 2, right).

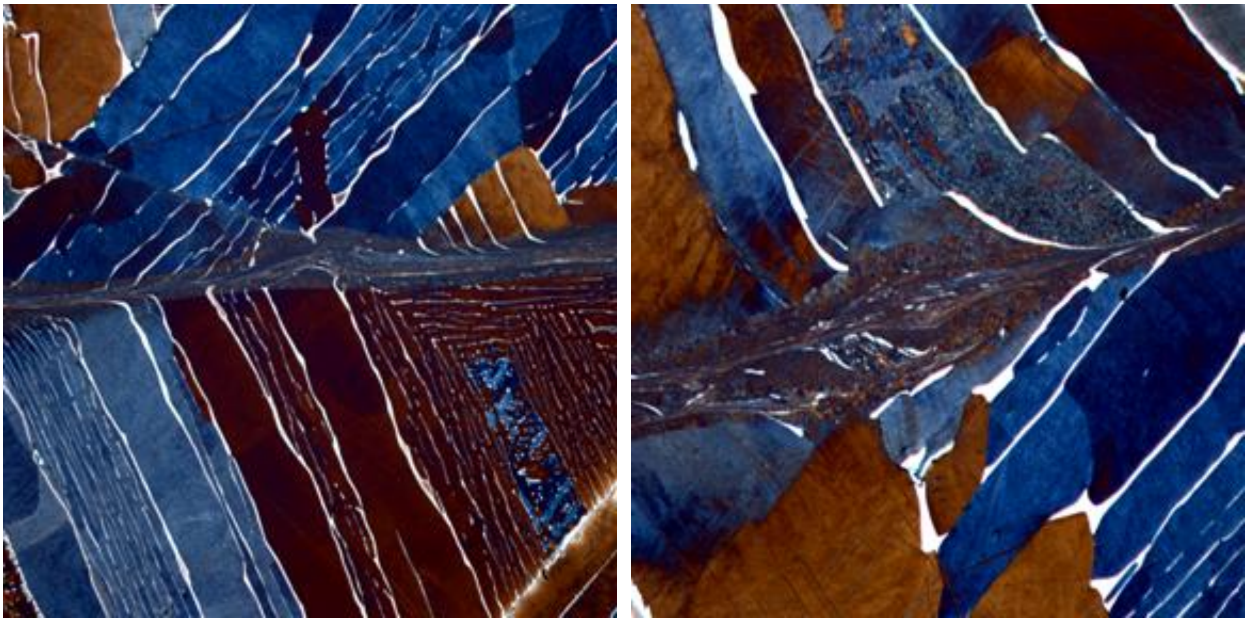

Figure 1: Examples of a heavy deformation band crossing the elongated, heavily deformed kamacite bands (colored). This white taenite can be seen between the bands. Some plessite is present in both images. Tint etched with Klemm's I reagent, viewed with polarized light and sensitive tint, 25X (left) and 50X (right).

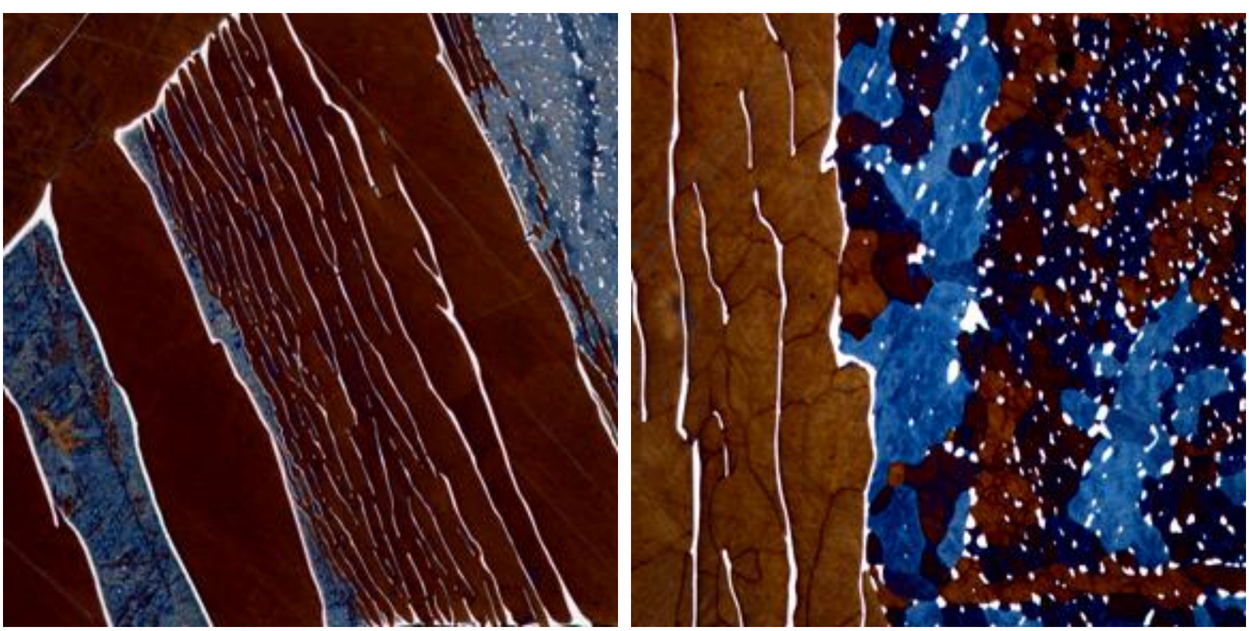

Figure 2: Examples of plessite patches (mixtures of kamacite and taenite) and kamacite bands separated by thin layers of taenite. The kamacite is heavily cold worked and contains sub-grain boundaries, particularly visible in the image at the right. Tint etched with Klemm's I reagent, viewed with polarized light and sensitive tint, 50 X (left) and 100X (right)

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