Microstructure of Fe-Ni Meteorites

George F. Vander Voort
Buehler Ltd
Lake Bluff, Illinois
Fe – Ni Meteorites

• Ni ranges from 4.3 to 34% (few >20%)
  • Cobalt present, 0.4 – 1%
    • Sulfur <0.6%
      • P <0.3%
      • C <0.2%
    • Small amounts of other elements
Fe – Ni Meteorites

Three Basic Types:

• Hexahedrites – Single Crystals, 
  Ni is usually 5.2 – 5.8%

• Octahedrites – Long Ferrite (Kamacite) grains, usually 5 – 10% Ni

• Ataxites – No Gross Macrostructure, 
  usually 15-18% Ni

• Anomalous types
Constituents in Meteorites

- Kamacite - ferrite
- Taenite - austenite
- Plessite - $\alpha/\gamma$ mixtures of various morphologies
- Cohenite – $(\text{Fe, Ni, Co})_3\text{C}$
- Rhabdite & Schreibersite – $(\text{Fe, Ni})_3\text{P}$
- Various minerals
Hexahedrites
Coahuila fell in Mexico. It is a single crystal containing kamacite (ferrite), Neumann bands and rhabdites, $(\text{Fe},\text{Ni})_3\text{P}$, in prismatic and plate-like shape. Etched with 100 mL water, 10 g $\text{Na}_2\text{S}_2\text{O}_3$, 3 g $\text{K}_2\text{S}_2\text{O}_5$. 

Coahuila – Hexahedrite

$\text{Fe} – 5.59\% \text{ Ni} – 0.45\% \text{ Co} – 0.28\% \text{ P}$
Coahuila – Hexahedrite
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Etching in boiling Murakami’s reagent for 20 s colored the prismatic rhabdites but none of the plate rhabdites.
North Chile – Hexahedrite

Fe – 5.59% Ni – 0.48% Co – 0.3% P

North Chile fell in Tocopilla, Chile. It is a single crystal of kamacite with Neumann bands, and rhabdites. Etched with Beraha’s sulfamic acid reagent.
Twins (T) and plate (P) and prismatic-shaped rhabdites revealed using 2% nital.
Plate (P) and prismatic-shaped rhabdites and twins (T) revealed using 2% nital and Nomarski DIC. Note that there is considerable fracturing in the rhabdites.
Octahedrites
Gibeon fell in Southwest Africa (Namibia). It contains kamacite, austenite (taenite) and plessite (ferrite-austenite mixtures) of several types. Etched with 100 mL water, 10 g Na\textsubscript{2}S\textsubscript{2}O\textsubscript{3}, 3 g K\textsubscript{2}S\textsubscript{2}O\textsubscript{5}.
Gibeon – Fine Octahedrite
Fe – 7.93% Ni – 0.41% Co – 0.04% P

Gibeon fell in Southwest Africa (Namibia). Here are two examples of plessite nested between kamacite grains that contain Neumann bands.
Etched with 100 mL water, 10 g Na₂S₂O₃, 3 g K₂S₂O₅.
Gibeon – Fine Octahedrite

Fe – 7.93% Ni – 0.41% Co – 0.04% P

Plessite revealed by etching with picral and nital. Picral reveals the interface between kamacite and taenite while nital reveals kamacite sub-grain boundaries and twins.
Gibeon – Fine Octahedrite

Fe – 7.93% Ni – 0.41% Co – 0.04% P

As Polished

4% Picral

Calcium silicates in Gibeon and a black plessite patch.
Henbury – Medium Octahedrite

Fe – 7.51% Ni – 0.45% Co – 0.09% P

Henbury fell in the Northern Territory of Australia. This region shows kamacite highly deformed by extra-terrestrial collisions. Etched with 100 mL water, 10 g $\text{Na}_2\text{S}_2\text{O}_3$, 3 g $\text{K}_2\text{S}_2\text{O}_5$. 

500 µm
Box Hole fell in the Northern Territory of Australia. Heat has recrystallized the octahedral kamacite. Remnants of plessite can still be observed. Etched with 100 mL water, 10 g Na₂S₂O₃, 3 g K₂S₂O₅.
Box Hole – Medium Octahedrite

Fe – 7.67% Ni – 0.49% Co – 0.11% P – 0.05% S

As-Polished

Daubreelite (Fe-Cr-S) with a partial rim of chromite (Fe-Cr-O), arrow
Arispe – Coarse Octahedrite

Fe – 6.70% Ni – 0.47% Co – 0.3% P

Arispe fell in Sonora, Mexico. Two examples of plessite are shown, pearlitic and spheroidized. Plessite is a mix of kamacite and taenite. Etched with Beraha’s CdS reagent.
Fairview – Coarse Octahedrite (IIIAB)
Found in 1986, Bailey County, Texas

Fairview fell in Texas. The coarse kamacite grains cover most of the field and contain Neumann bands (mechanical twins). Etched with Beraha’s sulfamic acid reagent (polarized light and sensitive tint).
Odessa – Coarse Octahedrite

Fe – 7.35% Ni – 0.48% Co – ~0.25% P – 0.5% S – ~0.2% C

Odessa fell in Texas. The field shows plessite between kamacite grains that contain Neumann bands. Some cell boundaries are also present within the kamacite grains. Etched with 10% Na₂S₂O₅, polarized light.
Odessa – Coarse Octahedrite

Fe – 7.35% Ni – 0.48% Co – ~0.25% P – 0.5% S – ~0.2% C

Odessa fell in Texas. Here we see two examples of martensite within taenite grains. The example on the left also shows the classic cloudy zone and a clear taenite zone, plus cracks.

Beraha’s CdS Reagent

2% Nital, Polarized Light
Odessa – Coarse Octahedrite

Fe – 7.35% Ni – 0.48% Co – ~0.25% P – 0.5% S – ~0.2% C

Odessa fell in Texas. Here is an example of an area containing graphite (green) and troilite (FeS). Viewed with polarized light and sensitive tint.
Canyon Diablo – Coarse Octahedrite

Fe – 7.1% Ni – 0.46% Co 0.26% P ~1% S ~1%C

Canyon Diablo fell in Arizona. Mechanical twins and sub-grain boundaries in kamacite revealed using Beraha’s reagent (100 mL water, 10 g Na₂S₂O₃, 3 g K₂S₂O₅)
Two examples of plessite in Canyon Diablo. At the right, the arrow points to cohenite. The white arrows point to a CT-1 zone followed by a dark CZ.
Canyon Diablo – Coarse Octahedrite

Fe – 7.1% Ni – 0.46% Co 0.26% P ~1% S ~1% C

Taenite wedges and martensite in Canyon Diablo. The arrows point to the CT-1 zone at the $\alpha$-$\gamma$ interface, then the dark CZ, retained taenite (CT-2) and martensite in the interior; 2% nital.
Canyon Diablo – Coarse Octahedrite

Fe – 7.1% Ni – 0.46% Co 0.26% P ~1% S ~1%C

Rhabdites colored brown by alkaline sodium picrate, 6 V dc, 40 s
Canyon Diablo – Coarse Octahedrite

Fe – 7.1% Ni – 0.46% Co 0.26% P ~1% S ~1%C

Sphalerite, ZnS, in the as-polished condition
Canyon Diablo – Coarse Octahedrite

Fe – 7.1% Ni – 0.46% Co 0.26% P ~1% S ~1%C

A patch of cohenite (C) and schreibersite (S) revealed using 2% Nital in a deformed, non-recrystallized kamacite region
Canyon Diablo – Coarse Octahedrite

Fe – 7.1% Ni – 0.46% Co 0.26% P ~1% S ~1% C

Schreibersite/cohenite particle etched with alkaline sodium picrate, 8 V dc, 60 s, which colored the cohenite dark, while not affecting the schreibersite.
Zagora - Octahedrite

Silicates in Zagora, etched with 2% nital. On the left, a particle of cohenite is visible along with some mechanical twins (Neumann Bands).
Ataxites
Washington County – Ataxite (Anomalous)

Fe – 9.9% Ni – 0.6% Co – 0.39% P

Washington County fell in Colorado. The structure is recrystallized, fine grained kamacite and small globular particles of taenite. Left - etched with 100 mL water, 10 g Na$_2$S$_2$O$_3$, 3 g K$_2$S$_2$O$_5$; Right – etched with Beraha’s sulfamic acid reagent.