Sulfides in Enstatite Chondrites: Indicators of Impact History

Kristyn Hill[1,2], Emma Bullock[2], Cari Corrigan[2], and Timothy McCoy[2]

[1]Lock Haven University of Pennsylvania, Lock Haven, PA 17745, USA

[2]National Museum of Natural History, Department of Mineral Sciences, Washington D.C. 20013, USA

Introduction

Enstatite chondrites are a class of meteorites. They are referred to as chondrites because of the spherical chondrules found in the matrix of the meteorites. Enstatite chondrites are the most highly reduced meteorites and contain iron-nickel metal and sulfide bearing minerals. The matrix is made up of silicates, enstatite in particular. There are usually no oxides found, which supports the idea that these formed in very oxygen poor environments. The enstatite chondrites in this study are type 3, meaning they are unmetamorphosed and not affected by fluids.

Studying enstatite chondrites will help us determine the evolution of their parent bodies which formed at the beginning of our solar system. These meteorites show similarities with the sulfur found on the surface of Mercury. This suggests that Mercury may have formed from similar materials and/or in a similar region of the solar nebula to the enstatite meteorites.

Analytical Techniques

- Samples studied are Antarctic Meteorites from the National Museum of Natural History Antarctic Meteorite Collection.
- Eight samples were examined in reflected light under a petrographic microscope. Reflected light images of sulfide mineral assemblages were taken to observe textural features using an OPELCO microscope.
- Images of the samples were stitched together using mosaicking software written in the Department of Mineral Sciences.
- Textures were observed to determine if samples were impact melted or unaltered.
- Compositions of minerals were obtained using a Scanning Electron Microscope (SEM) and analyzed using Noran System Six (NSS) software (Figure 2).

Mineral Spectra

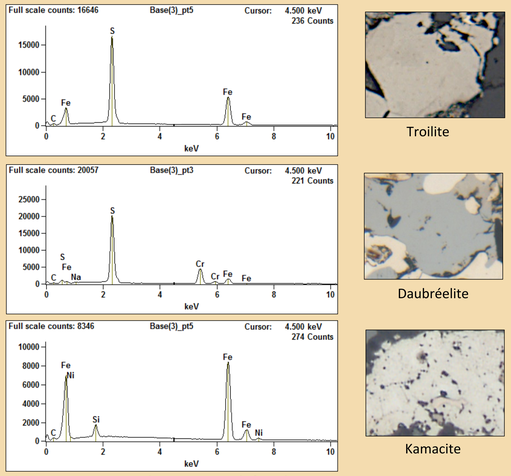


Figure 1. SEM spectra showing minerals found in various EH3 meteorites with reflective light images taken with a petrographic microscope to the right.

Results

Impact Melt, Slowly Cooled

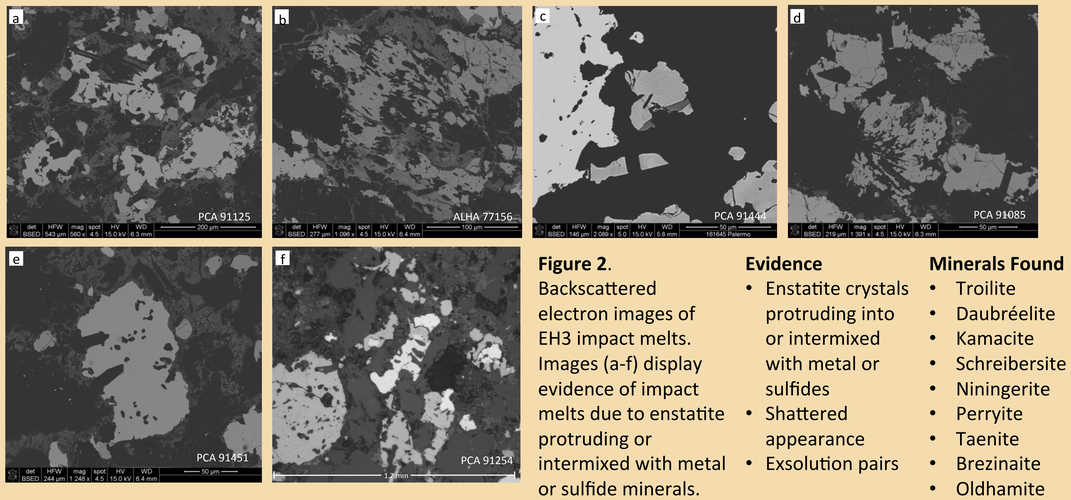


Figure 2. Backscattered electron images of EH3 impact melts. Images (a-f) display evidence of impact melts due to enstatite protruding or intermixed with metal or sulfide minerals.

Evidence
- Enstatite crystals protruding into or intermixed with metal or sulfides
- Shattered appearance
- Exsolution pairs

Minerals Found
- Troilite
- Daubréelite
- Kamacite
- Schreibersite
- Niningerite
- Perryite
- Taenite
- Brezinaite
- Oldhamite

Impact Melt, Quickly Cooled

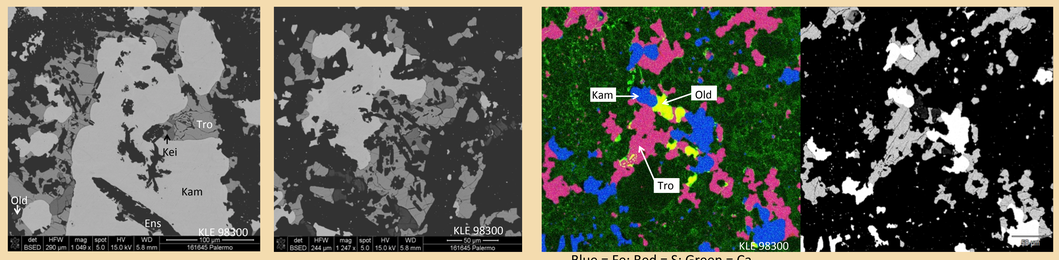
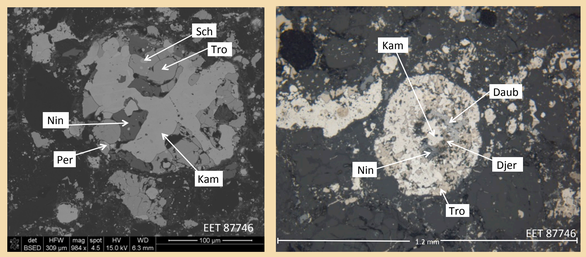


Figure 3. Backscattered electron images and spectral imaging of KLE 98300 displaying keilite as evidence for impact melt.

Evidence
- Enstatite crystals protruding into or intermixed with metal or sulfides
- Shattered appearance
- Presence of keilite
- Exsolution pairs absent

Minerals Found
- Keilite
- Troilite (Cr-rich)
- Oldhamite
- Kamacite
- Schreibersite
- Graphite

Unaltered by Impact Melt, Slowly Cooled



Evidence
- Enstatite crystals do not appear to be protruding into or intermixed with metal or sulfides
- Shattered appearance absent

Minerals Found
- Troilite
- Daubréelite
- Kamacite
- Schreibersite
- Niningerite
- Perryite
- Djerfisherite

Discussion

Determining the history of the parent body of a chondritic meteorite often includes distinguishing whether or not the meteorite was impact melted, and the cooling rate.

Impact melts are distinguishable by the texture of the metal and sulfide assemblages. A meteorite that was impact melted will contain a texture of euhedral to subhedral silicates, like enstatite, protruding into the metal or sulfides (figure 2). Some textures will look shattered (figure 2b). Meteorites that contain the mineral keilite are also an indicator of impact melts (figure 3). Keilite only occurs in enstatite chondrite impact-melt rocks that cooled rapidly (Keil, 2006).

Cooling rates can be determined by the suite of minerals present. Exsolution pairs occur when elements of one mineral have time to exsolve out to form another mineral, indicating a slow cooling rate. For example, troilite (FeS) and daubréelite ($FeCr_2S_4$) are exsolution pairs (figure 4). If they are both present in a sample, the meteorite cooled slowly. If daubréelite is absent, the meteorite cooled quickly, not allowing the Cr to separate from troilite. Therefore meteorites that cooled quickly will not have exsolution pairs.

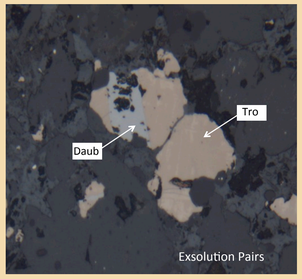


Figure 4. Exsolution pairs troilite and daubréelite in PCA 91258 (under reflected light) indicating slow cooling.

Future Work

- Examine other enstatite chondrites (EH4-6, and EL3-6) as well as known enstatite impact melts
- Measure the sulfur isotopic compositions of individual sulfide grains using the Cameca ims 1280 secondary ion mass spectrometer (SIMS) at the University of Hawai'i in collaboration with Dr. Gary Huss
- Look for other indications of impact melt (abundance of presolar grains) using the NanoSIMS at the Carnegie Institution of Washington

References

Keil, K., 2006. Occurrence and origin of keilite, (Fe>0.5,Mg<0.5)S, in enstatite chondrite impact-melt rocks and impact-melt breccias. Chem. Erde 67, 37-54.

Acknowledgements

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