ELECTRON BACKSCATTER DIFFRACTION (EBSD) OF SHERGOTTITES NORTHWEST AFRICA (NWA) 15628, NWA 12241, AND DHOFAR (DHO) 019.

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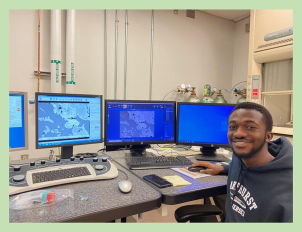


Introduction

- Martian meteorites are heavily deformed as a consequence of the shock impact processes that transferred them to earth.
- The degree of shock metamorphism is quantified using shock stage [1] and weighted shock stage [2] classifications which depend on observed shock metamorphic features under the petrographic microscope but these have the disadvantage of being somewhat imprecise [3] and ultimately somewhat qualitative.
- New Scanning Electron Microscope – Electron Backscatter Diffraction (SEM-EBSD) methods use plastic deformation in mineral grains to quantify the extent of deformation [4].
- EBSD metric known as Grain Orientation Spread (GOS), is very robust and Mean GOS is highly correlated with weighted shock stage.
- GOS measures the average misorientation within a grain [4]
- Goal: Evaluate shock effects in; Northwest Africa (NWA) 15628, NWA 12241 and Dhofar (Dho) 019 using optical petrography as well as SEM-EBSD methods.

Samples

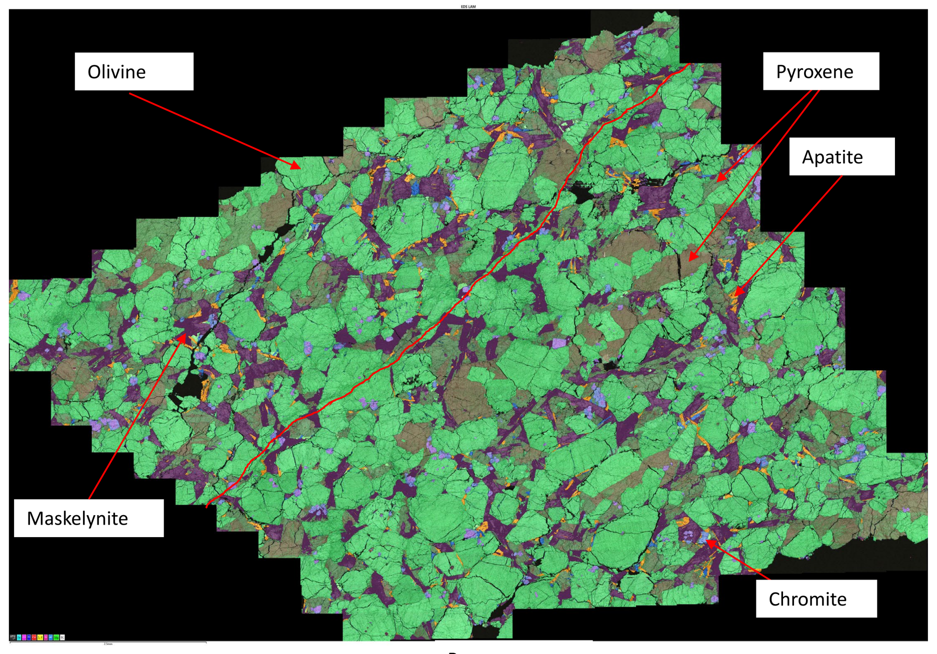
- NWA 12241
  - Poikilitic shergottite with olivine, pyroxene, birefringent plagioclase, and amorphous plagioclase [5].
  - Shock stage = low (M-S3)
- Dho 019
  - Olivine phyric shergottite consisting of pyroxene, zoned olivine megacrysts and fully converted maskelynite.
  - Shock stage = M-S4 but melt pockets are rare.
- NWA 15628:
  - Basaltic shergottite dominated by pyroxene and maskelynite.
  - Shock stage = M-S4 [6].
  - Experienced higher pressures and temperatures (P-T) than Dho 019 based on the size of melt pockets and intensity of fracturing

Methods

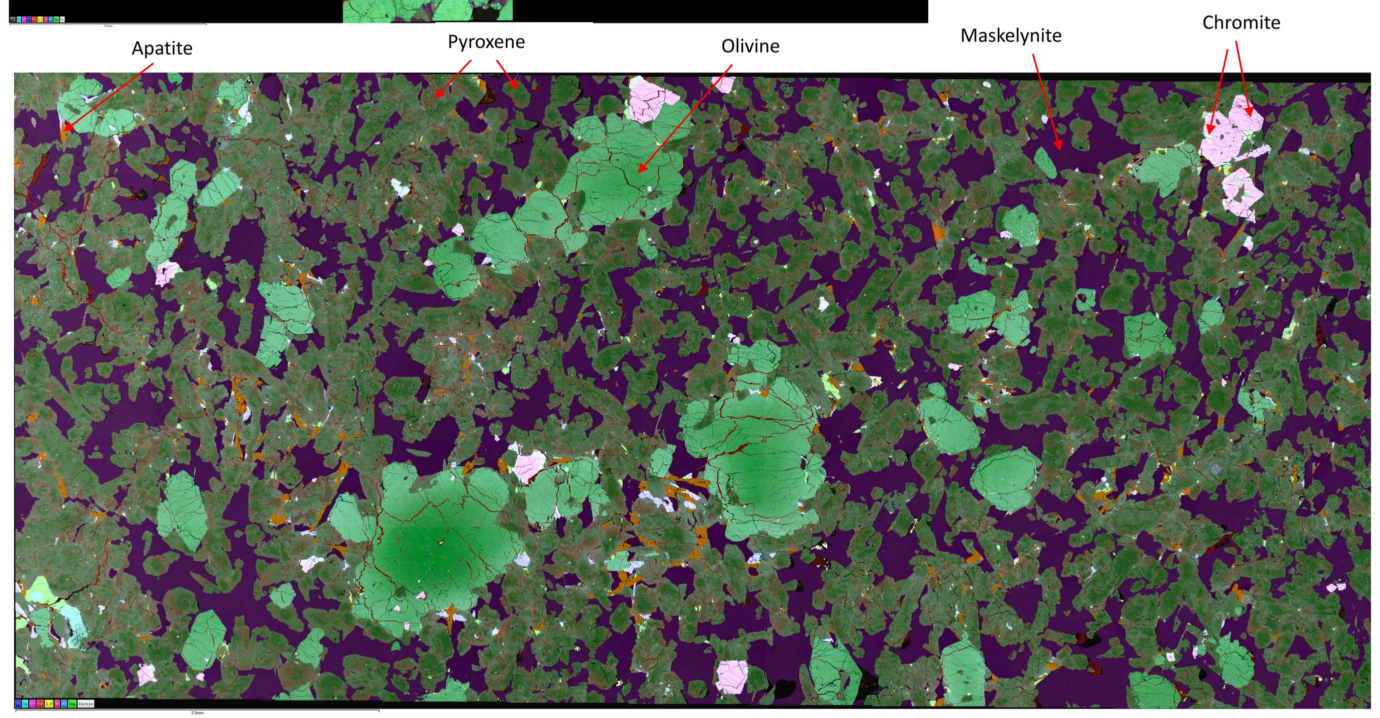
- Petrographic and shock stage analysis using the Leica DM2500 petrographic microscope.
- Hand polishing of thin sections using colloidal silica for ~60-61 minutes.
- ~3-5 nm carbon coat for SEM-EBSD analysis.
- Data collection using Scanning Electron Microscope at Portland State University.
- Data processing using AzecCrystal. Information about data collected can be found in table 1.
- Pigeonite and augite were combined and analyzed together as pyroxene.
- GOS values of grains with equivalent circle diameter >50µm (designated as $GOS_{d>50}$) are used because they correlate strongly with shock stage estimates [4].

Table 1: Area and number of grains analyzed for all samples

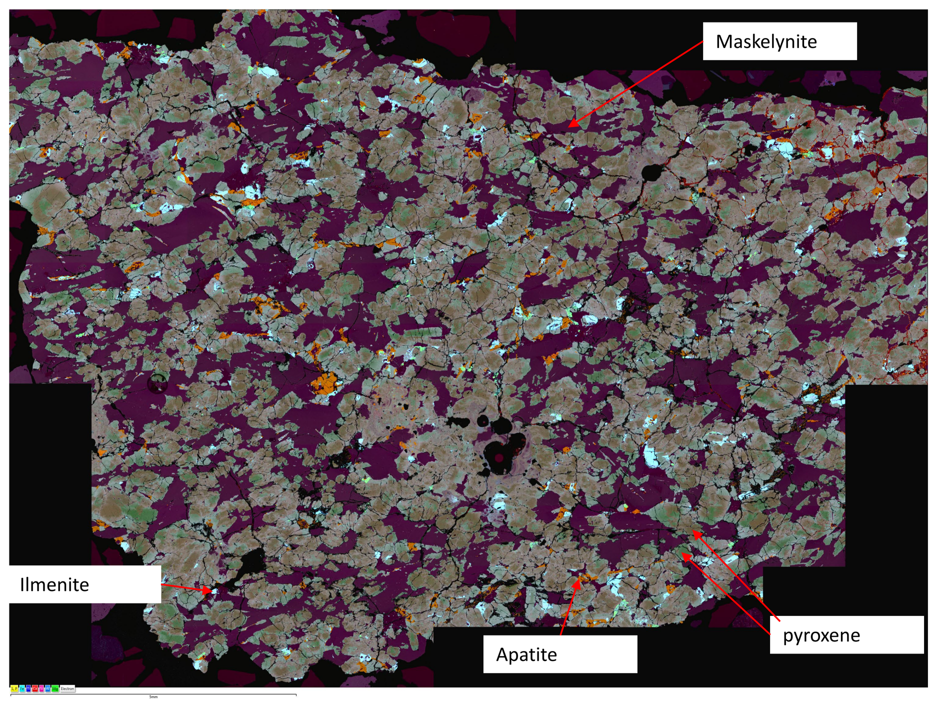
Sample	Map Area (mm²)	Step Size (µm)	Number of grains
NWA 12241	44.58	1	181,870
Dho 019	164.21	3	146,903
NWA 15628	14.93	1.5	66,680



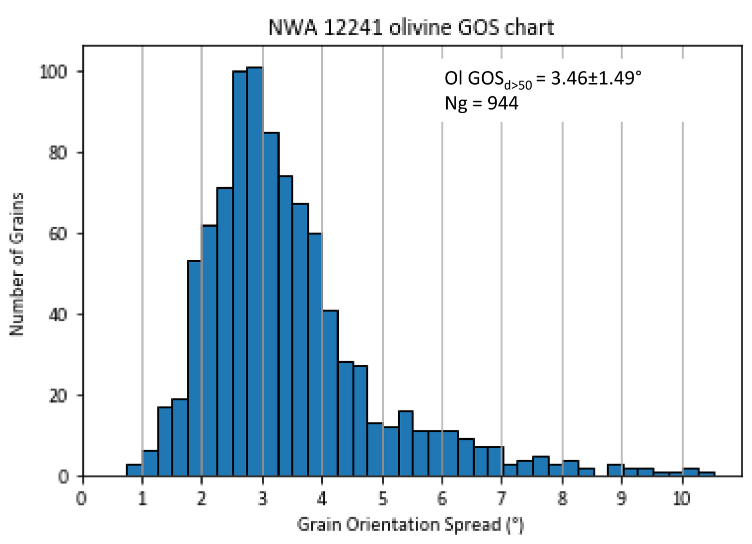
NWA 12241 False color EDS map. Elements shown are CaMgAlSiFePSTi + BC. Red line is the approximate location of a thin shock vein

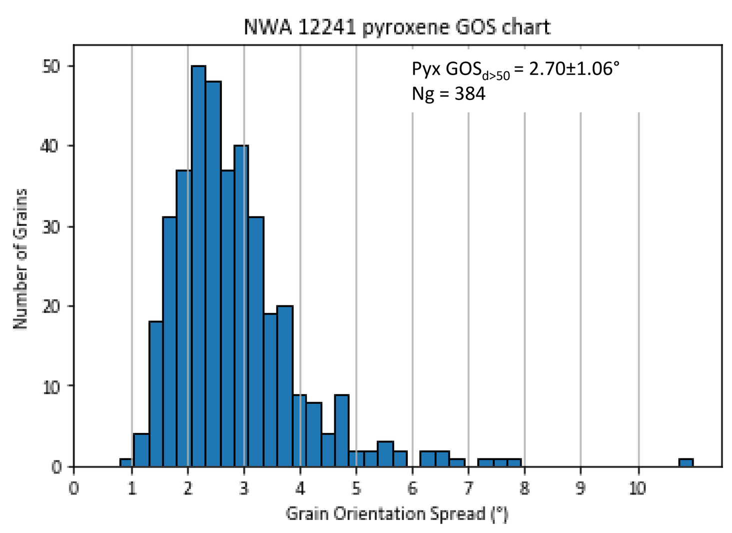


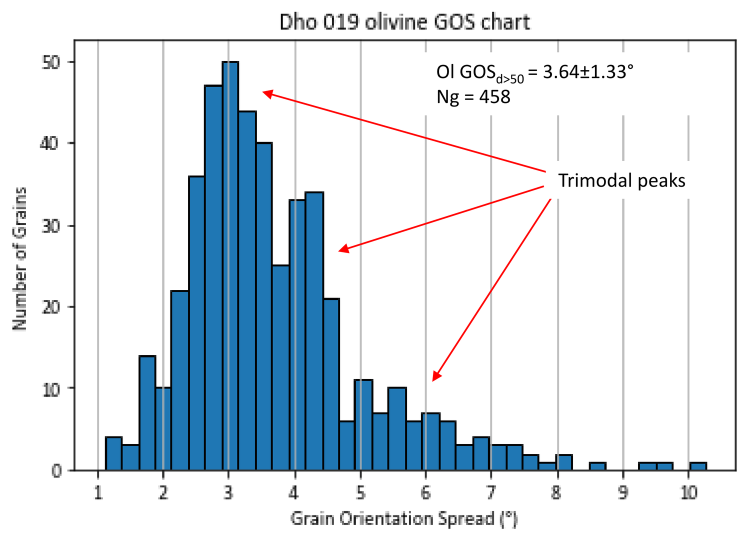
Dho 019 False color EDS map. Elements shown are CaMgAlSiFePSTi + Electron

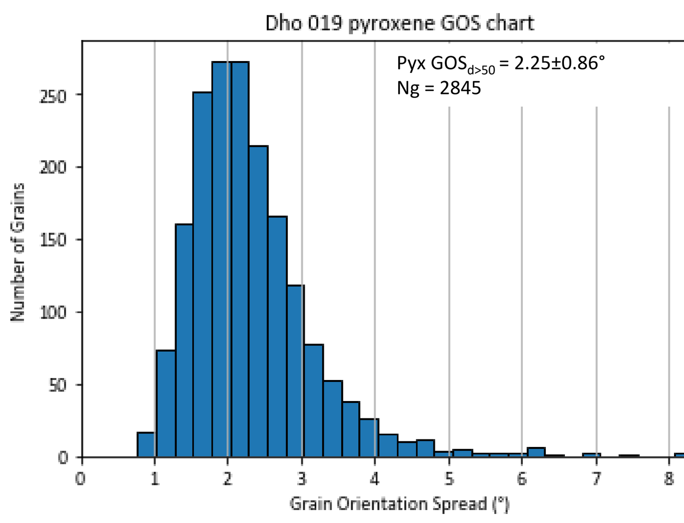


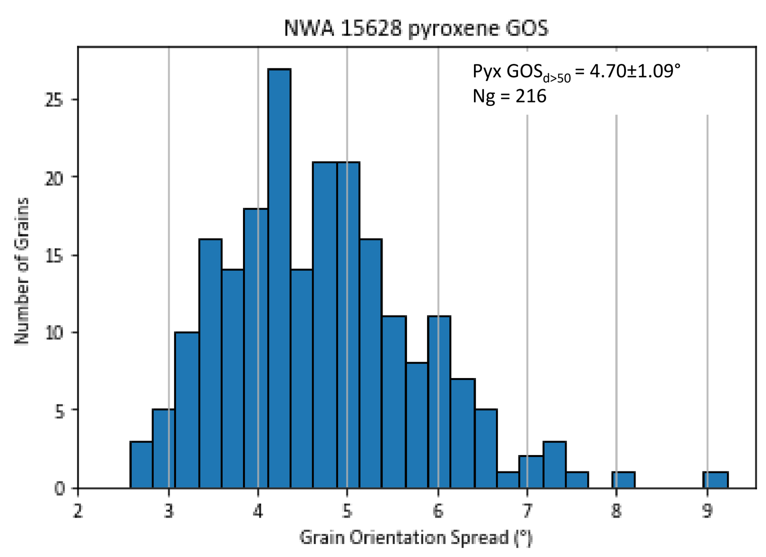
NWA 15628 False color EDS map. Elements shown are CaMgAlSiFePSTi + Electron











- GOS = Grain orientation spread = Average misorientation within a mineral grain given in degrees.

Results

- NWA 12241
  - Olivine (Ol) $GOS_{d>50}$ = 3.46±1.49°, Ng = Number of grains = 944
  - Pyroxene (Pyx) $GOS_{d>50}$ = 2.70±1.06°, Ng =384
- Dho 019
  - Olivine $GOS_{d>50}$ = 3.64±1.33, Ng = 458
  - Pyroxene $GOS_{d>50}$ = 2.25±0.86°, Ng = 2845
- NWA 15628
  - Pyroxene $GOS_{d>50}$ = 4.70±1.09°, Ng = 216

Discussion

- Olivine GOS follows expected trend consistent with shock stages similar to [4].
- Olivine GOS is generally higher than pyroxene GOS similar to unpublished data by Ruzicka.
- Px GOS for Dho 019 is slightly lower than in NWA 12241 even though NWA 12241 has a lower shock stage. Causes might be:
  - **Higher olivine to pyroxene ratio in NWA 12241** which subsequently leads to higher shock impedance contrasts across the entire rock.
  - **Thin shock vein** across NWA 12241 may have anomalously increased the mean GOS for all phases.
- ***Trimodal peaks*** observed in Olivine GOS charts for Dho 019 could be due to:
  - **Magmatic deformation prior to shock**.
    - This is not supported by the petrographic textures.
  - **Preference for higher deformation along certain olivine crystallographic axis**.
    - Comparison between olivine GOS and olivine orientation maps does not support this.
  - **Multiple impacts**.
    - But expect trimodaility for pyroxene and chromite which isn't observed.
  - **Shock impedance contrasts**.
    - But no definite relationship between GOS and proximity to low density phases such as maskelynite or high density phases such as olivine and chromite.
  - ***Grain fracturing during shock***.
    - But population of fractured grains with higher GOS are too low to be the predominant contributor.
    - *However the smaller grain size for the lowest GOS peak supports the idea that these grains could have spalled off of larger deformed crystals*

References

[1] Stöffler et al (2018) MaPS, 53, 5–49, 2018. [2] Jamsja and Ruzicka (2010), MaPS, 45, 828–849, [3] Stöffler (1991) Geochimica et Cosmochimica Acta, 55, 3845–3867. [5] A. Udry et al. (2021), LPSC 52, Abstract # 2548. [6] Met. Bull. Database, https://www.lpi.usra.edu/meteor/metbull.php. [4] Ruzicka and Hugo (2018) Geochimica et Cosmochimica Acta, 234, 115–147.

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