CONSTRAINTS ON FABRIC-FORMING MECHANISMS IN SHERGOTTITE NWA 6963: RESULTS FROM MINERALOGY AND SHAPE-PREFERRED ORIENTATION. J. Filiberto[1], J. Gross[2], J. Trela[1], and E.C. Ferré[1], [1]Southern Illinois University, Department of Geology, Carbondale, IL 62901, Filiberto@siu.edu, [2]American Museum of Natural History, New York, NY 10024.

Introduction: Northwest Africa (NWA) 6963, found in Morocco in 2011, was classified as a basaltic shergottite based on mineralogy [1, 2]. This meterite consists of pyroxene grains up to several mm in length, set in a coase grained matrix of maskelynite, ferroan olivine, spinel, ilmenite, merrillite, apatite, Fe-sulfides and high Si-glass [1]. NWA6963 is extremely coarse grained compared with the other basaltic shergottites (**Fig 1**). Pyroxene grain size compares to that of pyroxenes in terrestrial gabbros and microgabbros rather than from basaltic or volcanic rocks [3, 4]. This suggests an intrusive setting for the crystallization conditions of NWA 6963. Therefore, combining mineral chemistry and shape-preferred orientation (SPO) data can potentially constrain the crystallization and fabric-forming processes for NWA 6963. Recent studies of fabric analysis on Martian shergottites emphasized anisotropy of magnetic susceptibility (AMS) and electron backscatter diffraction (EBSD) techniques [5, 6]. Using AMS, [5] showed that Martian meteorites preserve their magmatic fabrics, and display a degree of oblateness similar to terrestrial volcanic and plutonic rocks. Using EBSD on Zagami pyroxene, [6] showed that the pyroxene grains have a planar fabric but not a corresponding lineation. Further, previous work summarizing textural analyses of pyroxene in basaltic shergottites suggested that the alignment of pyroxenes occurred during eruption and flow of a basaltic magma with cumulate pyroxenes entrained in the magma [7].

Here, we quantified 2-D SPO of NWA 6963 using a technique commonly employed for terrestrial rocks that has a high sensitivity for shape anisotropy (0.3% error) [8-10]. We use these results, in combination with mineral chemistry, to constrain the processes that formed magmatic fabrics on Mars and compare these results with previous conclusions.

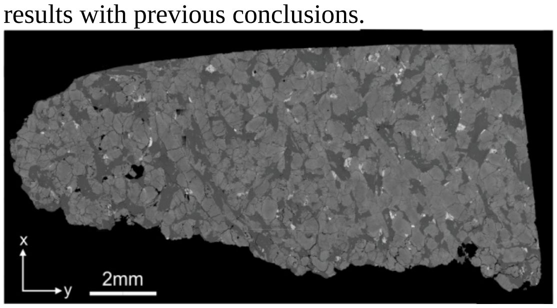

Figure 1. Back-scattered electron image (BSE) of NWA 6963.

Methods: *Electron Microprobe:* Mineral chemical analyses were obtained with an electron microprobe (Cameca SX100) at the American Museum of Natural History (AMNH). Operating conditions include: 15 kV acceleration voltage, 20 nA beam current; focused beam (1 μm) except for maskelynite (defocused beam of 10 μm in size). Peak and background counting times were between 30 s and 10 s per element.

Shape-Preferred Orientation Method: The Intercept method [10] provides a convenient and easy method for fabric analysis. This technique consists of counting the number of intercepted points of an object, e.g., pyroxene crystals on a digital image, by a set of parallel scan lines along a number of orientations using Intercept2003 freeware. Image analysis by the Intercept method provides information complementary to the LPO and AMS methods by using digital images and computer-assisted analyses [8, 9].

Elongated pyroxene crystals (pigeonite and augite) were first hand-traced onto a transparency fixed to a computer screen. Hand-tracing is preferred because automatic tracing does not easily distinguish fractures from grain boundaries. The elongated, tabular-shaped pyroxene grains constitute potential passive markers of deformation and thus the best candidate for SPO studies. The transparency was scanned and converted into a binary images (black and white), of 2196 pixels by 1704 pixels. Parallel scan lines intercepted points per 9° rotation (step-angle), yielding 40 directional measurements. Intercept2003 determined whether or not each intercepted point belonged to the mineral phase being analyzed and produced rose diagrams (polar plots) based on the number of intersected points in each respective 9° rotation.

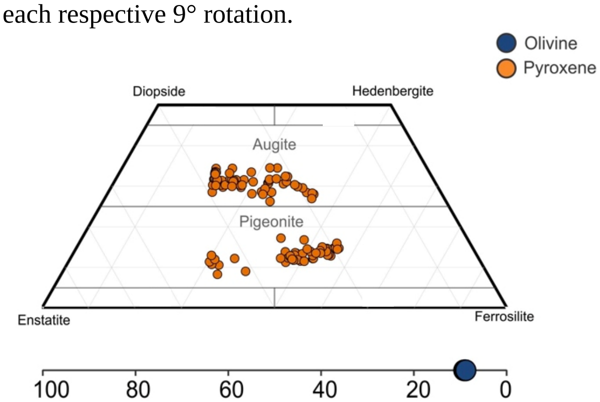

Figure 2. Pyroxene and olivine compositions in NWA 6963.

Results: *Mineralogy:* Similar to many basaltic shergottites [7], two populations of pyroxenes exist in NWA 6963: augite and pigeonite. The pyroxenes are in equilibrium and give a high T crystallization of ~1250°C and low T of ~1000°C from [11, 12]. Al/Ti ratios of the pyroxene [from 13, 14] suggest crystallization beginning at upper crustal depths. Olivine is fayalitic (~Fo_{10}) suggesting it was a late stage crystallization product.

SPO Results: The rose of directions displays the dominant shape-preferred orientation of pyroxene fabric (**Fig 3**). The X and Y axes correspond to the edges of the original back-scatter electron (BSE) image and provide a spatial framework for orienting dominant petrofabric trends (**Fig 1**). The direction of the X-axis equals 0° while the direction of the Y-axis equals 90°. The shape ratio (SR), represented by a best-fit fabric ellipse, equals the length of the long fabric axis divided by the short fabric axis and the SR for NWA 6963 equals 1.356. The dominant fabric orientation corresponds to 153° with respect to the X axis. These preliminary 2D results provide information on the strength of the fabric but do not resolve the rock fabric in 3D for which 3 perpendicular thin-sections would be required. However, we will further constrain these results using EBSD techniques at the AMNH.

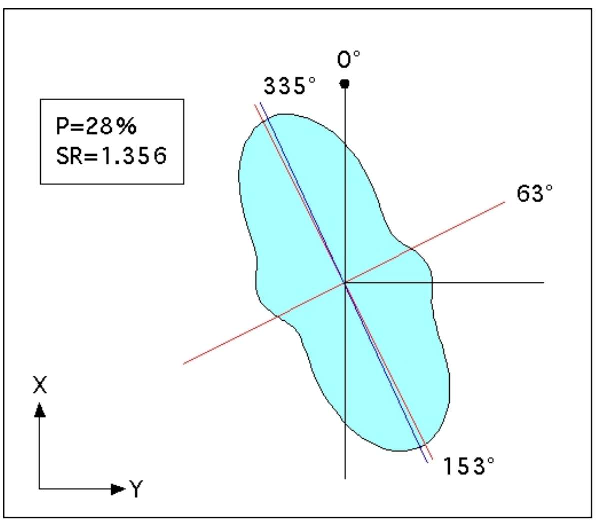

Figure 3. Rose of directions for the shape-preferred orientation of pyroxene fabric in NWA 6963.

Discussion and conclusions: The high SR indicated by image analysis and apparent lack of plastic deformation microstructures in pyroxenes suggests that magmatic deformation occurred on Mars. [7] suggested that the pyroxene alignment in shergottites was caused by eruption and flow of magmas with entrained pyroxenes. This was based on the orientation of the large pyroxene grains combined with the fine grained nature of the mesostasis in many shergottites. However, NWA 6963 is a relatively coarse grained rock rulling out eruption and surficial flow as cause of the orientation. At this time, no crystal-plasticity was observed in the sample. However, EBSD analyses will clarify whether or not the meteorite underwent crystal-plastic deformation. Excluding crystal-plasticity, our results suggest several probable fabric-forming processes: i) compaction of a crystal mush by crystal-settling or in situ crystallization, ii) alignment due to magmatic flow, and iii) mechanical segregation of crystals due to magmatic flow. The coarse-grained texture and high degree of shape-preferred orientation of the sample indicate three probable fabric-forming processes: 1) subsurficial magmatic flow, 2) crystal-settling/compaction or 3) a combination of both.

References: [1] Wilson N. et al (2012) LPSC 43, Abstract #1696. [2] Meteoritical Bulletin (2011) MaPS. [3] Cawthorn R.G. (1996) Layered intrusions, Elsevier, 531. [4] Wager L.R. and Brown G.M. (1967) Layered igneous rocks,W. H. Freeman 588. [5] Gattacceca J. et al. (2008) EPSL, 270, 280-289. [6] Becker T.E. et al. (2011) 42nd LPSC, Abstract #2474. [7] McSween H.Y. (1994) Meteoritics, 29, 757-779. [8] Launeau P. et al. (2010) Tectonophysics, 492, 230-239. [9] Launeau P. et al (1990) Tectonophysics, 180, 201-211. [10] Launeau P. and Robin P.Y.F. (1996) Tectonophysics, 267, 91-119. [11] Lindsley D.H. (1983) AmMin, 68, 477-493. [12] Andersen D.J. et al (1993) Computers and Geosciences, 19, 1333-1350. [13] Nekvasil H. et al. (2007) MaPS, 42, 979-992. [14] Filiberto J. et al. (2010) MaPS, 45, 1258-1270.