GRANITIC COMPOSITIONS IN GABBROIC MARTIAN METEORITE NWA 6963: EVIDENCE FOR EXTREME FRACTIONAL CRYSTALLIZATION OF A HYDROUS MAGMA. J. Gross[1,3], and J. Filiberto[2]; [1]American Museum of Natural History, Dept. of Earth and Planetary Sciences, New York, NY 10024; [2]Southern Illinois University, Geology Dept., Carbondale, Il 62901; [3]Lunar and Planetary Institute, Houston, TX 77058 (jgross@amnh.org)

Introduction: Felsic rocks such as granite and the volcanic equivalent, rhyolite, are common on Earth where they crystallize from highly evolved siliceous melts formed from magmatic processes associated with plate tectonics. These siliceous melts can be produced from a parent magma through extensive fractional crystallization [1,2]. There is little evidence that Mars had plate tectonic and it seems to be dominated by basaltic rock that has experienced little magmatic evolution [3,4]. Recently, [5] and [6] reported spectral analyses from CRISM onboard the Mars Reconnaissance Orbiter for felsic rocks from several locations throughout the martian surface, and Mars Science Laboratory (MSL) Curiosity Rover also discovered felsic rocks and soils [7-9] near Gale Crater. However, until recently felsic/granitic compositions were missing from the meteorite collection. Martian meteorite breccia NWA 7034 (and pairs), a recent discovery, is the first sample that contains more felsic rock types such as trachyte [17].

Meteorite Northwest Africa (NWA) 6963, a gabbroic shergottite, crystallized completely within the crust [10], and contains quartz-feldspar intergrowths that has a late-stage granitic melt composition. Here we report mineralogy, petrography, and textures of two types of granitic compositions found in this meteorite and discuss the implications of our results for the geological history of Mars.

Method: NWA 6963 was studied by backscattered electron (BSE) and X-ray elemental mapping imagery, and mineral chemistry. BSE images, element maps (Fig. 1) and mineral analyses were obtained using a Cameca SX100 electron microprobe (EMPA) and a Zeiss EVO 60 Scanning Electron Microscope (SEM) at the American Museum of Natural History, NY. Operating conditions were: 15kV accelerating voltage, 10-20nA beam current (minerals), 40nA (mapping), and a focused beam (1 micron) for minerals. A beam diameter of 20 microns was used for broad beam analyses, in oder to calculate the bulk compositions of the granitic types. Measurement times were 20-30s per element. Standards included well characterized natural and synthetic materials.

Texture, Petrography and Mineralchemistry: Mineralogically, NWA 6963 is composed of 65 ±5 % pyroxene, 30 ±5 % maskelynite, and minor ferroan olivine, spinel, ilmenite, merrillite, apatite, and Fe-sulfides [10]. NWA 6963 also contains two types of granitic compositions (Fig.1): a micro-graphic type (type 1) and a microcrystalline/glassy type (type 2).

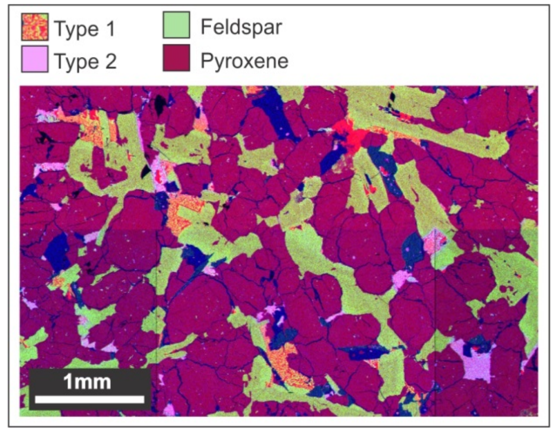

Figure 1: *RedGreenBlue (SiNaK) map of NWA 6963 showing two types (1 and 2) of granitic compositions.*

Type 1: The areas of quartz and feldspar intergrowths (Fig. 1) can be up to ~1 mm in length. The phases were course grained enough to be identified based on single EMPA data as well as element compositions from geochemical maps. Texturally, the quartz and feldspar intergrowths (Fig. 2) occur as regular arrangements mostly with sharp edges and corners but can also occur irregularly in shape and can be defined as micrographic – a cuneiform, regular intergrowth of quartz and alkali-feldspar that resembles the graphic intergrowth of terrestrial pegmatites but on a microscopic scale [10].

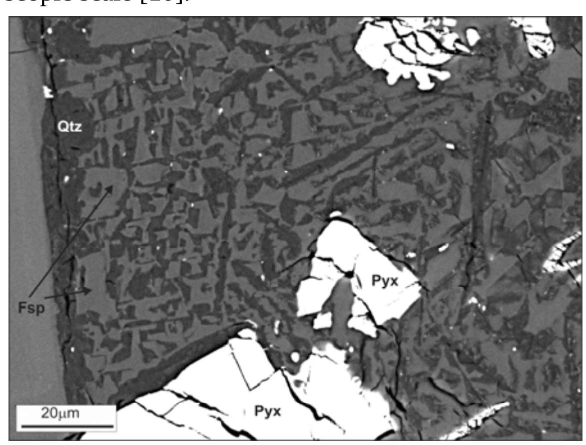

Figure 2: *Typical micro-graphic texture of the granitic composition type 1. Pyx=pyroxene; Qtz = quartz; Fsp = feldspar.*

The average bulk composition of the type 1 areas (mixture of quartz and feldspar, seen as a linear trend in figure 3) cluster within the granitic field with a total alkali content around 4 wt% (that contains only small amounts of K_2O between 0.2 - 0.5 wt%) and an average Si_2O content of ~80 wt% (Table 1).

Table 1: *Representative analyses of granitic compositions type 1 and type 2.*

	Type 2	Type 1
Sample number	A1	A8
P_2O_5	0.19	0.20
SiO_2	78.64	80.36
TiO_2	0.52	0.23
Al_2O_3	11.79	12.14
FeO	0.65	0.69
MnO	0.02	0.01
MgO	0.01	0.03
CaO	0.49	3.44
Na_2O	3.32	3.61
K_2O	5.16	0.43
Total	100.79	101.16

Type 2: Texturally, the granitic areas of type 2 are very fine grained/glassy. Geochemically, these areas have a higher total alkali content (~ 8wt%) due to the higher potassium content (~5wt% K_2O; Table 1). The SiO_2 content is within error of that from the type 1 compositions.

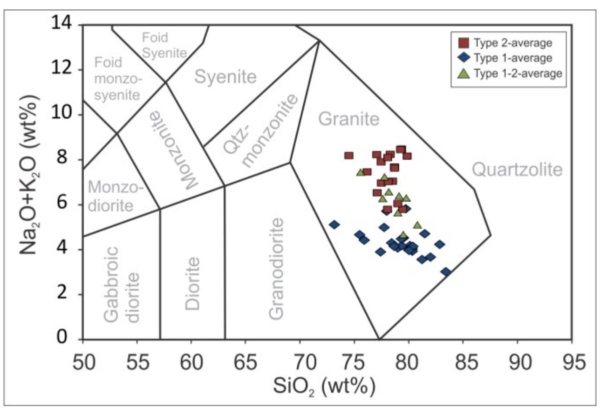

Figure 3: *Granitic compositions of type 1 (blue diamonds) and type 2 (red squares). Both compositions fall within the granitic field. Green triangles represent areas that gradually went from type 1 into type 2 . Fields are from [11].*

Discussion: Graphic intergrowths of quartz and feldspar are common in terrestrial plutonic rocks [e.g., 12,13], though, these intergrowths are rare in volcanic rocks. Texturally, intergrowths, such as in type 1, in terrestrial samples are suggestive of simultaneous crystallization of quartz and feldspar at the eutectic point [12-14]. Similar to terrestrial micrographic intergrowths, this suggests that the intergrowths in NWA 6963 formed from a late-stage simultaneous eutectic crystallization of quartz and feldspar [10].

Extensive work has been done on the origin of terrestrial granite. The present lack of plate tectonics on Mars suggests that terrestrial intraplate magmatism would be more relevant on Mars than granite formed in subduction zones. Intraplate magmas on Earth commonly produce a suite of diverse rocks through fractional crystallization that can range in composition from basalt to rhyolite [15]. Similarly, the finding of small pockets of potassic-granitic-like melt composition, such as type 2 in NWA 6963, is consistent with extreme fractional crystallization within the martian crust. The pressure must have been midcrustal due to the low total alkali content and high K_2O content compared to terrestrial high pressure granites [1, 2]. However, experimental fractional crystallization results, simulating intraplate magmatism of terrestrial basalts at ~4 kbar, have shown that a moderate bulk water content of ~>0.3 wt% is required in order to produce potassic-granitic compositions, such as type 2 in NWA 6963 [15]. This suggests that the parental melt of NWA 6963 contained water contents similar to that of primitive terrestrial basalts which is consistent with NWA 6963's apatite chemistry and volatile fugacity ratios [16].

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