GRANITIC COMPOSITIONS IN GABBROIC MARTIAN METEORITE NWA 6963 AND A POSSIBLE CONNECTION TO FELSIC COMPOSITIONS ON THE MARTIAN SURFACE.

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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, felsic/granitic compositions are missing from the meteorite collection so far.

Meteorite Northwest Africa (NWA) 6963, a gabbroic shergottite, crystallized completely within the crust [10], and contains a quartz-alkali feldspar intergrowth 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. BES images, element maps (Fig. 1) and mineral analyses were obtained using a Cameca SX100 electron microprobe (EMPA) at the American Museum of Natural History, NY. Operating conditions were: 15kV accelerating voltage, 10-20nA beam current (minerals), 40nA (mapping), focused beam (1 micron) for minerals and a beam diameter or 20 microns for broad beam analyses, to calculate the bulk compositions of the granitic areas. Measurement times were 20-30s per element. Standards included well characterized natural and synthetic materials.

Sample: NWA 6963 was found at an undisclosed location in Morocco in 2011, and was classified as a martian gabbroic shergottite [10]. For this study two surfaces of a doubly polished thick section were analyzed.

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 granite type (type 1) and a glassy granite type (type 2).

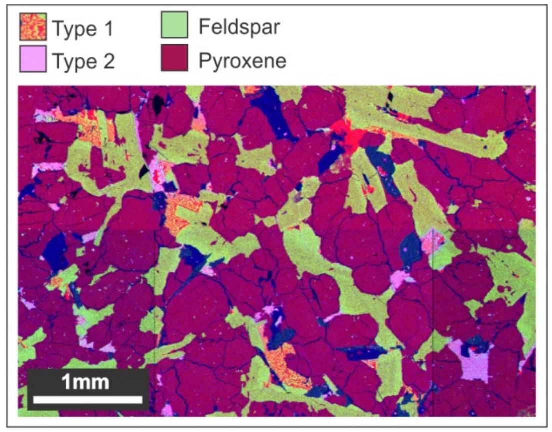

Figure 1: *RedGreenBlue (SiNaK) map of NWA 6963 showing two types (1 and 2) of granitic compositions.*

Type 1: The areas of quartz and alkali-feldspar intergrowths can be up to ~1 mm in size (Fig. 1). 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].

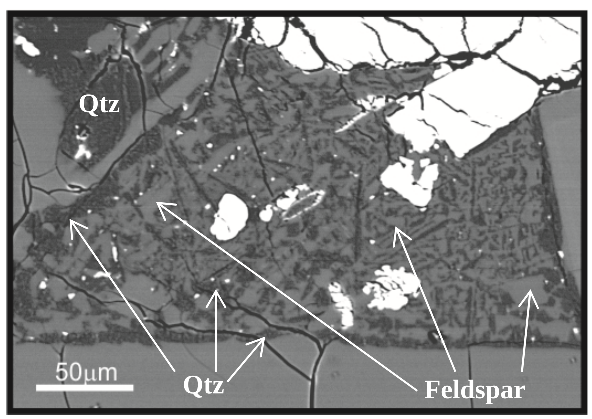

Figure 2: *Typical micro-graphic texture of the type 1 granitic area.*

Feldspar within the intergrowth is alkali-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, with ~78wt%, is slightly lower than in the type 1 areas.

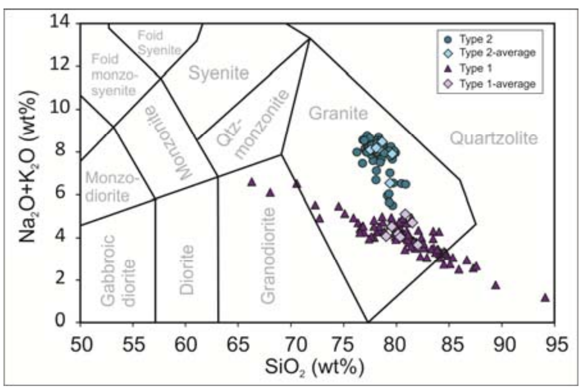

Figure 3: *Granitic compositions of type 1 and type 2 areas. Both average type compositions (diamonds) fall within the granitic field. Fields are from [11].*

Discussion and Implications: Graphic intergrowths of quartz and alkali-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 alkali-feldspar [10]. Granitic composition type 2 represents ver fine grained/glassy areas which lack intergrowth texture. Both granitic types seem to follow a trend towards more alkali and lower silica compositions. Interestingly, both types occur distinctly from one another; only two areas were located in which the texture and composition changed from graphic granite type 1 to glassy type 2. Such distinct separation is possible through liquid immiscibility, and not uncommon in terrestrial basalts [15,16]. Thus, it is likely that at the end of the crystallization of NWA 6963, the residual melt separated and crystallized into two distinct compositions: one with high Na, low K, and higher Si content (type 1), and a second one with high K and lower Si content (type 2).

The two types of granitic compositions in NWA 6963 show that this rock finished crystallizing within the interior of Mars, agreeing with the micro-gabbroic texture of this rock. The pressure must have been low due to the low total alkali content compared to terrestrial high pressure granites [1,2], supporting the conclusion by [10] that the rock most likely completely crystallized somewhere in the crust. The finding of small pockets of granitic-like melt composition in a gabbroic host in NWA 6963 is consistent with the surface of Mars which is mainly basaltic in composition with only a few possible siliceous areas found from orbit [e.g., 17-19]. Therefore, there may be isolated siliceous bodies within the martian crust that formed from fractional crystallization of a martian basalt such as NWA 6963. Results from experimental fractional crystallization and computational modelling of martian basalts have already shown that martian granitic compositions are plausible [e.g., 5, 20-23]. This is supported by the recent orbital remote sensing discovery of felsic rock compositions on the martian surface [5,6]. This indicates that processes associated with extensive magma evolution have been more prevalent on Mars than previously thought and could help explain the felsic compositions found by MSL [7-9].

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