PETROGENESIS OF A VITROPHYRE IN THE MARTIAN METEORITE BRECCIA NWA 7034. A. Udry¹, N. G. Lunning¹, and H. Y. McSween Jr.¹, ¹Planetary Geosciences Institute, Dept. of Earth and Planetary Sciences, University of Tennessee, Knoxville, TN 37996, USA.

Introduction: The martian meteorite breccia Northwest Africa (NWA) 7034 and its paired meteorites NWA 7533 and NWA 7475 are the first samples of martian regolith available for study on Earth. These are likely polymict breccias because separate clasts have chemical compositions [2-4] that are not consistent with a single source. NWA 7034 contains a variety of clasts, similar to clasts also described in NWA 7533: gabbroic clasts consisting of pyroxene, feldspar, phosphates, and oxides, phosphate-rich clasts containing the same phases as the gabbroic clasts, but with larger apatites and oxides, a mugeartite clast, a trachyandesite clast, and two types of “melt” clasts [1-3]. [1] found small melt spherules, and a large vitrophyric clast containing skeletal pyroxene and olivine in a glassy matrix.

We focused our study on this single large vitrophyric clast in NWA 7034 (Fig. 1). This melt clast has a texture not previously observed in martian meteorites and may represent a new martian composition. It is likely to be compositionally representative of the protolith rock based on its large size (5 x 4.5 mm) and relatively fine-grained texture.

Fig. 1 X-Ray Mg map of the whole NWA 7034 vitrophyre clast.

Results and Discussion: Modal abundances in the clast are 75% glass, 18% pyroxene, and 7% olivine. The edges of the clast show a 300-µm wide rim that is distinct from the clast interior. This rim contains finer-grained acicular pyroxene aligned parallel to the contact, as well as a higher abundance of Fe-oxides and an absence of olivine. The elongated skeletal pyroxene grains show slight compositional zoning, with an average core composition of En99Wo1Fs28 and average rim composition of En69Wo3Fs32. The olivine grains have a hopper-like texture and are zoned with compositions of Fo55-63. The olivines are too Fe-rich to be in equilibrium with the pyroxenes. The groundmass is generally composed of glass, most of which has a nearly homogeneous basaltic composition. Different localized compositions of glass likely represent silica and alkali feldspar in the protolith that were not fully homogenized during melting. The pyroxene in the vitrophyre is enriched in light REE (LREE) compared to pyroxenes in other martian meteorites.

We calculated the bulk-vitrophyre major element composition using modally weighted EMP analyses of pyroxene, olivine, and the common basaltic glass (Fig. 2). The vitrophyre plots in the basaltic field in the TAS diagram and has an alkali content similar to Gusev basalts, whereas the bulk-breccia composition [1] shows enrichment in alkalis compared to the vitrophyre and martian meteorites (Fig. 2b). Si, Al, and Mg contents of the vitrophyre are closer to Gusev basalt compositions than to any martian meteorites. The NWA 7034 whole-breccia composition [1] is lower in Fe (10 wt %) than the vitrophyre (15.5 wt%), Gusev basalts, and most of the martian meteorites (Fig. 2a). Some clasts observed in NWA 7533 by [5] defined as clast-laden impact melt rocks (CLIMR) have similar major element compositions to the NWA 7034 vitrophyre and more closely resemble the latter than the NWA 7034 host breccia. In addition, the vitrophyre clast composition falls in the Gusev soils field [6] except it is more enriched in Fe than Gusev soils. The vitrophyric clast pattern is parallel to the NWA 7034 host breccia REE pattern [1].

The skeletal textures of both olivine and pyroxene suggest a high degree of undercooling. According to crystal growth experiments, these features correspond to very fast cooling rates, on the order of thousands of degrees Celsius per hour [7-8].

Ni content in the bulk-vitrophyre (1020 ppm) is significantly higher than in other martian basalts, including the whole-rock NWA 7034 breccia (392 ppm) [1] but is similar to the Gusev soils. Additionally, the Ni content of the vitrophyre is higher than in NWA 7533 CLIMR (589 ppm) [5], which are unambiguously impact-melt rocks based on their Ir concentration. If the vitrophyre formed by impact melting of the Gusev basalt Humphrey (Mg/Ni = 382), the indigenous Ni would be 170 ppm and thus 850 ppm Ni would be from a non-martian source. The exogenic Ni is equivalent to 7.7 wt % CI chondritic contamination.

Low Zn and S concentrations suggest that the protolith of the vitrophyre did not include martian soil. The absence of a soil component differs from both the
host breccia and the observations of the NWA 7533 CLIRM [5].

The vitrophyre bulk major and trace element composition is different from the NWA 7034 bulk-breccia composition [1]. Using the least-squares method, we compared the bulk composition of the vitrophyre to known martian igneous rock compositions: the vitrophyre composition most closely resembles Humphrey rock, one of the Gusev basalts (Fig. 2). Thus, it is very likely that this vitrophyre represents an impact melt of a martian basalt with a Humphrey-like composition that was contaminated by a chondrite impactor.

Summary and Conclusions: The vitrophyre is an impact melt. The exogenic Ni component (850 ppm) is evidence for its impact origin, as is its occurrence with CLIRM in a regolith breccia.

Based on the vitrophyre’s bulk composition, the protolith was not the host breccia but another martian rock. We compared it to all analyzed martian basalts, and the major element composition of the bulk-vitrophyre is most similar to the Gusev crater basaltic rock Humphrey. We infer that the target rock was a Humphrey-like igneous rock, for which we did not have a meteorite analog prior to this study.

These martian breccias potentially include samples of other igneous lithologies that are not represented by currently described martian meteorites.


Fig. 2. Bulk composition diagrams for NWA 7034 bulk vitrophyre, basaltic, olivine-phyric, and lherzolite shergottites, nakhlites, Chassigny, ALH 84001, Bounce Rock, and Gusev basalts (Adirondack, Humphrey, Mazatzal) and soils from [6;9-23]. These various compositions are plotted on: a) Mn-Fe (wt%) diagram with martian meteorite lines [6], b) Total alkalis versus silica (wt%) diagram, c) Ca/Si-Mg/Si (atomic ratio) diagram used for classification of martian meteorites, d) Mg/Si-Al/Si (atomic ratio) diagram, and e) Ni (ppm)-Mg diagram with terrestrial and martian fractionation lines [6].