OXIDE PHASES AND OXYGEN FUGACITY OF MARTIAN BASALTIC BRECCIA NORTHWEST AFRICA 7034.

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Introduction: Northwest Africa 7034 is a 2.1 Ga basaltic breccia [1], which was recenty classified as a new type of martian meteorite [2]. One of the noteworthy characteristics of NWA 7034 is the relatively high abundance of Fe-bearing oxide phases, with estimates from X-ray powder diffraction indicating >10% oxide minerals. These oxide minerals are distributed throughout the matrix of the breccia, and they are also present within the three lithologic clast types that have been identified in NWA 7034 [3]. Based on preliminary analyses of the oxide phases in NWA 7034 [1] indicated substantial ferric iron components in the oxides, indicating that NWA 7034 is not only the most water-rich martian meteorite, but it may also be the most oxidized. In fact [4] indicated a significant maghemite component in the meteorite to account for the magnetic properties of NWA 7034. In the present study, we aim to characterize the oxides within NWA 7034 and relate the oxide mineralogy to each of the lithologic clast types that have been identified [3].

EPMA characterization of oxides in NWA 7034: Multiple sections from NWA 7034 were examined using the JEOL 8200 electron microprobe at UNM to determine major and minor element compositions of oxides from the breccia matrix and in different clast types. Oxides were identified in all textural regimes of NWA 7034, and thus far we have identified Cr-rich magnetite, hematite-rich ilmenite, an oxide phase that is likely magnetite but could also be Ti-bearing hematite, and a few Fe-rich oxide phases that could not be identified from EPMA data alone.

TEM characterization of oxides in NWA 7034: Using EPMA data alone, it was difficult to differentiate between Ti-bearing hematite and ulvöspinel. Given the possibility of substantial low-temperature alteration of NWA 7034 at the martian surface, we felt the need to independently verify the structure of the oxide phase in association with hematite-rich ilmenite, so we used electron diffraction to confirm the presence of magnetite (Fig. 1). For this preliminary examination, magnetic phases from a split from a sieved subsamples of NWA 7034 were separated, powdered, mounted on a TEM grid, and analyzed using TEM/STEM/ EFTEM (transmission electron microscopy for nano-scale imaging, scanning TEM for chemical contrast, and energy filtered TEM for imaging specific chemical species). Results from the analyses are shown in Fig. 1.

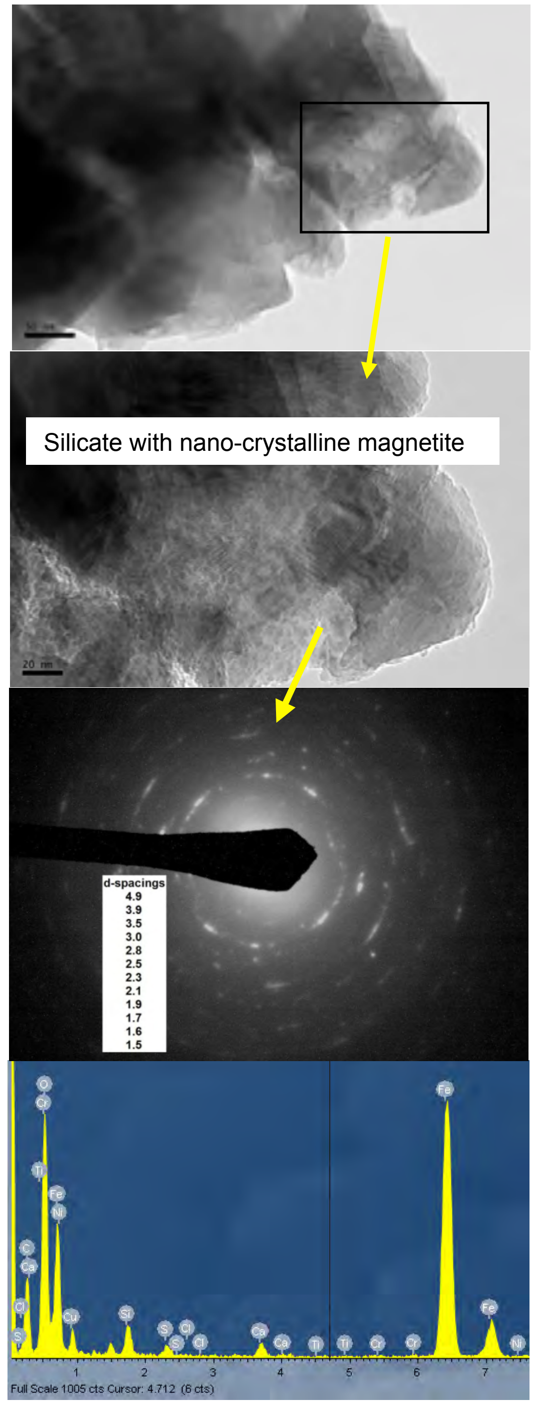

Fig 1. Upper two figures show TEM images of the nano-crystalline magnetite coating silicate in the powder sample. EDS and electron diffraction ring pattern (lower left and right images) were used to identify the magnetite.

Confirmation of the presence of magnetite with ilmenite allowed us to plot all of the EPMA data of the oxides on the Ternary oxide plot (Fig. 2).

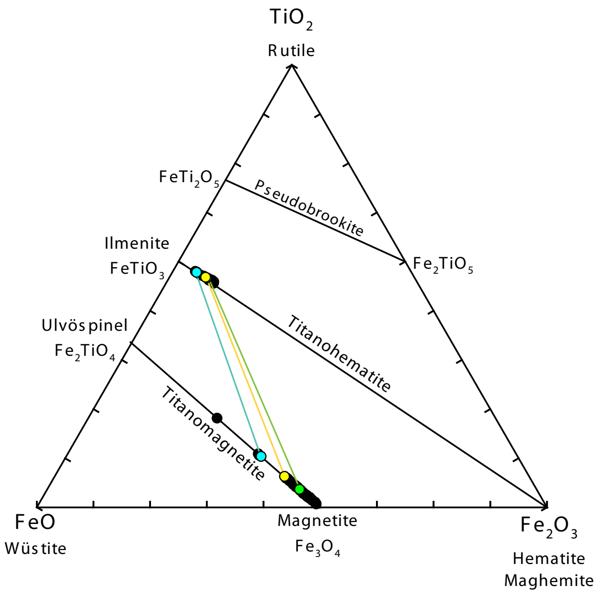

Fig. 2. Ternary plot of Fe-Ti oxide components. All structural formulae were calculated based on a cation normalization, which includes charge balancing Fe^{2+} and Fe^{3+}. Three ilmenite-oxide pairs were identified from three different textural regimes of NWA 7034. Cyan points represent the gabbroic clast, the phosphate clast pair is yellow points, and the green points are for an oxide pair in the matrix.

Oxygen Fugacity: Given the confirmation of Magnetite-ilmenite pairs, one can begin to make estimates of oxygen fugacity during the cooling of NWA 7034. In fact, ilmenite-magnetite pairs were texturally identified in the matrix of the breccia, in a phosphate clast [3], and in a gabbroic clast [3]. An example of an ilmenite-magnetite pair is presented in Fig. 3. The oxide pairs were identified texturally and the temperatures and oxygen fugacity relative to the fayalite-magnetite-quartz oxygen buffer were computed using the program QUILF (Quartz, Ulvospinel, ILmnite, and Fayalite) [5]. QUILF assesses equilibria among augite, pigeonite, orthopyroxene, olivine, Ti-magnetite, ilmenite, and quartz. It is based on an internally consistent thermodynamic model that describes the partitioning of Fe^{3+}, Fe^{2+}, Ti, Al, Mn and Mg into the aforementioned ferromagnesian minerals. The ilmenite portion of the model, which was crucial to this study, is based on an asymmetric multicomponent Margules solution that was originally presented in [6].

Ilmenite-magnetite pairs were identified in a phosphate clast, a gabbroic clast, and in the matrix of the breccia. The mineral pairs are also indicated on the oxide ternary plot in Fig. 2. The gabbroic clast has an oxide pair that indicates equilibration at 700 ^oC and +1FMQ (cyan points in Fig. 2). An oxide pair in a phosphate clast indicates equilibration at 700 ^oC and +2FMQ (yellow points in Fig. 2). The oxide pair from the matrix indicates an equilibration temperature of 650 ^oC and +3FMQ (cyan points in Fig. 2). All of these analyses indicate some of the most oxidizing post-magmatic environments for any martian meteorite and even exceeds the estimated oxygen fugacity of nakhlite Miller Range 03346, which was previously dubbed the most oxidized martian meteorite [7].

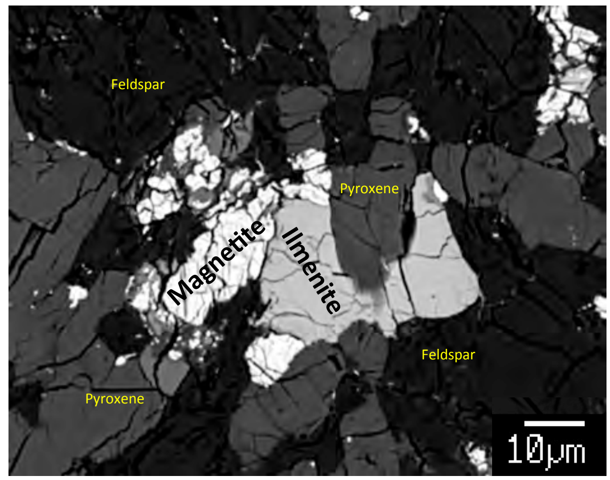

Figure 1. Backscatter electron (BSE) image of magnetite-ilmenite pair in a gabbroic clast in NWA 7034.

References: [1] Agee C. B. et al. (2013) *Science, 90,* 1151–1154. [2] Meteoritical Bulletin 101 (2013). [3] Santos et al. (this conference). [4] Rochette et al. (this conference). [5]. Andersen, D.J. et al. (1993) *Comput. Geosci.* 19, 1333. [6]. Andersen, D.J. et al. (1991) *Am Min.* 76, 427. [7]. Dyar, M. D. et al. (2005) *JGR-Planets*. 110, E09005.