Revisiting Accessory Minerals in the Martian Regolith Breccia Northwest Africa 7533

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Northwest Africa 7533 (and Northwest Africa 7034 pairing group) is an exceptional martian meteorite as it is a polymict regolith breccia, revealing unprecedented insights into the martian crust [1]. Along with in situ observations by MSL Curiosity [2] and reconstruction models of the primitive crust [3], this meteorite has completely changed our view of the martian crust. It provides evidence of magma differentiation processes leading to a primitive felsic crust starting before 4.2-4.4 Gy, with insights into local thermal history, marked by a possible metamorphic event resetting U-Pb systems at 1.6-1.7 Gy [4,5]. This regolith breccia exhibits an impressive petrological diversity, with clasts ranging from basaltic, to noritic and monzonitic composition, with other impact-related objects and even sedimentary fragments. Accessory minerals, like phosphates and zircons, are present in the matrix and in the different clasts. Characterizing and dating these minerals has been critical for deciphering the history of NWA 7533, from the formation of its clasts to their dislocation and compaction. In this study, we used different analytical techniques in order to explore in detail the structural and chemical characteristics of phosphates and zircon. First, Raman and luminescence spectroscopy, including hyperspectral mapping, were used to obtain a detailed overview of their structure (Raman) and Rare-Earth Element (REE) content (luminescence). SEM and cathodoluminescence imagery, as well as TEM on FIB sections and SIMS analysis on key zircons were subsequently performed on several polished sections of NWA 7533.

Zircons: In-depth Raman investigations show that NWA7533 zircons display wide textural variability, including heterogeneities at the grain scale. Perfectly crystallized areas coexist with highly degraded domains, caused either by disruption of the crystalline lattice and/or sub-micrometer mineral inclusions. Using TEM on FIB sections, the nanoscale texture of these zircons and the nature of the inclusions will be carefully discussed, considering preliminary results showing zonation of Si- or Fe-S- rich phases and magnetite. The textural characteristics can be related to the zircon petrological settings, as well as U-Pb ages and U content. We thus identified three main populations of zircons. Those analyzed in microbasaltic clasts show high homogeneity in shape, size and a high-level of crystallinity, with ages around 4.4-4.2 Gy and low U-content (≈10 ppm). Zircons scattered in the matrix generally display a great variability in shapes and textures, and Raman analysis shows that they have a larger structural heterogeneity ranging from well crystallized to nearly amorphous. These degraded zircons range in age around 1.5 Gy and have a high U content (≈100-300 ppm). Finally, zircons from feldspathic shards show intense textural variations at the grain scale, with alternation of preserved and degraded domains. In addition, REE luminescence spectra are different between these three populations of zircons, further supporting that these three zircon populations were not crystallized at the same magmatic stage and/or from the same magma.

Phosphates: These minerals are important reservoirs of trace elements and water making them good targets for dating as well as excellent tracers of magmatic evolution and alteration processes. Using Raman spectroscopy, merrillite and apatite (mainly chlorapatites with some fluorapatites) are detected and appear structurally homogeneous throughout the samples although a spectacular diversity of microtexture is observed. On the other hand, luminescence spectra exhibit a more complex pattern with strong trivalent REE signatures (from Er^{3+}, Sm^{3+}, Eu^{3+} and Dy^{3+}) in merrillite and associated overgrown apatite mantles (in a noritic clast) while the REE luminescence disappears in almost all apatite grains not associated with merrillite. Together with microtextural observations, this suggests the possible existence of at least two generations of apatites: one coming from the retrograde metamorphism of merrillite, the other being directly crystallized from a REE-depleted magma.

Concluding remarks: These data open new questions on the thermal and geochronological history of NWA7533.

Raman trends from amorphous zircons seems to follow data from terrestrial metamict zircons [6], which is further supported by high U-content and lower ages. But metamictization cannot fully explain the presence of degraded domains, apparent sub-micrometer inclusions still open the possibility of fluid alteration processes, which remains to be discussed, as they are not observed in the rest of the breccia. In addition, variability in luminescence patterns suggests two different generations of apatites with different formation mechanisms.

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