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The crystal structure and chemistry of natural giniite and implications for Mars

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Abstract

Investigations of planetary processes using phosphate minerals often focus on igneous, recrystallized, or potentially metasomatized minerals, likely as a result of the minerals commonly available for study within meteorites and lunar samples. However, Mars is a relatively phosphorus-rich planet and possesses abundant evidence of past aqueous surface interactions. Therefore, secondary phosphate phases may be important on the martian surface. Giniite [$Fe^{2+}Fe^{3+}_4(PO_4)_4(OH)_2 \cdot 2H_2O$] is a secondary phosphate mineral that has been suggested as a potentially significant phase at locations in Gusev Crater and Meridiani Planum on Mars. Although relatively rare as a natural mineral on Earth, giniite has gained attention as an important mineral in industry and technology, especially the lithium battery industry, and the ferrian version of the mineral is often synthesized. This suggests giniite may be important as an in situ resource utilization (ISRU) target for future extended human missions to Mars. Despite this, there are few data available on the natural mineral and the last characterization of the structure was over 40 years ago. There has also been confusion in the literature as to whether giniite is orthorhombic or monoclinic. In this work we revisit and document the chemistry and crystal structure of natural giniite from the type locality at the Sandamab pegmatite in Namibia using updated techniques. Our results refine and update what was previously known regarding the structure and chemistry of giniite and support the potential of the mineral as a possible martian scientific and resource target for further study to aid future missions.

Keywords: Giniite, Fe-phosphate, ferrous giniite, ferric giniite, ferrian, phosphate, hydroxyphosphate, martian habitability, Mars, ISRU, XRD; Earth Analogs for martian Geological Materials and Processes