

Interpreting phosphate mobility on Mars and the implications for habitability

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Phosphate is a crucial nutrient on Earth, used by life in ATP, DNA, RNA and phospholipid membranes [1]. Phosphate has also been proposed as essential in the prebiotic formation of RNA on Earth [2]. Interpreting phosphate behaviour on Mars is therefore important in characterizing habitability. Phosphate mobility on Mars, however, differs in important ways from phosphate mobility on Earth. In addition to fluorapatite, common on Earth, chlorapatite and merrillite are important primary phosphate minerals in martian meteorites [3-5]. Amorphous and poorly crystalline secondary phases have been documented on Mars [6, 7], suggesting that amorphous phosphate phases may similarly be important to the phosphate cycle on Mars. Environmental conditions affecting the behaviour of secondary phosphates such as oxidation state, pH, and water: rock ratios also likely differ between Earth and Mars. In order to interpret phosphate mobility on Mars, we are therefore performing dissolution experiments, investigating apatite weathering in the field, and modeling using the reactive transport code CrunchFlow.

Mineral dissolution rates are being measured of the phosphate-rich primary minerals fluorapatite, whitlockite, merrillite and chlorapatite, which are found in Mars meteorites. Due to the likely importance of amorphous phases, dissolution rates are also being measured of amorphous Al- and Fe-phosphate. Thin sections of weathered basalt from the phosphate-rich Mars analog Craters of the Moon, ID [8] are being examined to interpret phosphate mobility during incipient weathering. These data are then being used in reactive transport modeling of phosphate behavior under Mars-like conditions.

Measured dissolution rates suggest that whitlockite dissolves more quickly than fluorapatite at pH values < 4. Preliminary results suggest that amorphous Fe-phosphate dissolves more rapidly than its crystalline counterpart. Phosphate availability on Mars may therefore be greater than on Earth, with important implications for habitability. Reactive transport modeling indicates that secondary phosphate phases may preserve important environmental characteristics of habitability, including pH, water: rock ratio, and oxidation state. Future analyses of phosphate on Mars will likely yield important characteristics of possible habitability.

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The Crystallization of a Layered Mafic Sill from the Neoproterozoic Franklin LIP, Victoria Island, Arctic Canada

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A diabasic sill with an olivine-enriched base from the Neoproterozoic (ca. 723 & 716 Ma) Franklin LIP has been studied in detail through the combined use of whole-rock and in-situ mineral compositions, accompanied with detailed petrology and textural observations. The Franklin LIP has a well-exposed, unmetamorphosed, sill-dominated plumbing system, outcropping within the Shaler Supergroup, in the Minto Inlier of Victoria Island. The Shaler stratigraphy is riddled with sills and is capped by the ≤ 1 km thick Natkusiak flood basalts. A significant amount of magma has passed through this plumbing system, with a large portion of it remaining as sills in the crust. Whole-rock data from numerous sill chills sampled across the Minto Inlet region indicate two populations of magmas: 1) a younger diabasic event with flatter REE profiles; and 2) older diabasic sills characterized by LREE enrichment, some of which have olivine-enriched zones near their base. Of the latter type, the >40m thick Uhuk massif is thought to be one of several fault-controlled magmatic feeder zones within the Franklin LIP, and has a thick ol-rich layer. The >20m thick 'Lower Pyramid sill' from the Boot Inlet region, occupies the same stratigraphic position as the Uhuk massif, and we propose an explicit correlation of the two, with the Lower Pyramid representing a well-preserved distal (>40 km) injection of the same magma.

The Lower Pyramid sill has been divided into 7 facies zones: 1) a lower chilled margin (LCM); 2) a lower border zone (LBZ); 3) an olivine-cumulate zone (OZ); 4) a pyroxene-cumulate zone (PZ); 5) a diabase zone (DZ); 6) an upper border zone (UBZ); and, 7) an upper chilled margin (UCM). Due to the relatively rapid cooling regime of this sill and the occurrence of an olivine-rich base, the Lower Pyramid sill provides a snapshot into differentiation mechanisms operating within basaltic magma reservoirs. Using detailed petrography, coupled with whole-rock and in-situ mineral chemistry, a model of crystallization is proposed. During the initial emplacement of magma within the sill, melt chilled rapidly against the 'cold' host rock preserving a parental melt composition with 13% MgO. This was followed by crystallization of the LBZ and UBZ. The UBZ is characterized by acicular clinopyroxene with long axes oriented towards the roof, indicative of rapid heat loss in the upper sill margins. After the initial emplacement of the sill, olivine (trapped in the LCM and LBZ), clinopyroxene and plagioclase began to crystallize. As the early melt emplacement event continued to crystallize, the sill was re-intruded by a relatively primitive magma (~22% MgO) charged with olivine crystals, injected along the interface between the LBZ and the DZ. This incoming melt interacted with the rocks of the host intrusion, resetting some of its crystal composition values (An in plagioclase and Mg in clinopyroxene). The distribution of such zoning seems to suggest a complex interaction of melt and crystals in a cooling permeable mush when the olivine-slurry came in. There is also an increase seen in Fo and NiO content within olivine at the boundary of the olivine-zone, which contrasts with the more normal fractionation trends displayed in the LCM and LBZ. Some olivine crystals within the LBZ and the OZ display NiO-Fo decoupling trends, with NiO peaks towards the rim, which may well be caused by the influx of primitive melts sourced from the olivine-slurry, soaking into the LBZ mush below. The upper section of the olivine-zone has a 'harristic'-like texture suggesting that the DZ mush may have been largely crystallized and fairly cold at the time of the olivine replenishment event. As the OZ crystallized, residual melts enriched in SiO₂-Al₂O₃-CaO-Na₂O-K₂O might have percolated up through the OZ mush to pond below the diabasic rocks and affected the PZ, characterized by evolved plagioclase and clinopyroxene rims. Both plagioclase and clinopyroxene core compositions within the PZ fall on the same trends as the corresponding cores in the LBZ and DZ, which may also imply that there was a population of micro-phenocrysts entrained within the original magma. The DZ above the PZ is dominated by typical ophitic gabbros indicating the co-crystallization of plagioclase and clinopyroxene, with both cumulus and interstitial Fe-Ti oxides (as well as biotite and amphibole).