ROCK TEXTURES AND THE COATING ANALOGUES AT THE PATHFINDER LANDING SITE AND THIEL MOUNTAINS, INLAND ANTARCTICA.

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Introduction: This study compared the rock surface weathering processes of the site of the Mars Pathfinder (MPF) and Nolan Pillar, one of the most inland nunataks (rock outcropping surrounded by ice) in the Thiel Mountains, Antarctica. Nolan Pillar is one of the Earth's coldest and most arid snow-free places. The small pits on the surface of the rocks are important common features of both places. The surface coating is uneven and faces away from direct solar radiation at both sites. The coating materials of MPF site have been investigated by comparing the Alpha Proton X-ray Spectrometer (APXS) and the Imager Mars Pathfinder (IMP) multispectral data. However, the processes associated with the texture and coating of the rock surface is still unclear. Similar phenomena exist on the Antarctic rocks. Nolan Pillar is a small nunatak in the southeasternmost part of the Thiel Mountains (85º26' S, 86º46' W and ca. 1600m). Granodiorite porphyry samples were taken from the lowest part of the southeast-facing perpendicular rock wall of the pillar and moraine. The rock surfaces of the Thiel mountain samples were analyzed by Energy Dispersion Spectrometry (EDS) and X-ray Diffractogram (XRD) of the surface and interior of the rock. The pit holes were observed by the Scanning Electron Microscope (SEM).

Weathering of Inland Antarctica:

1) Optical microscopy and SEM

Thin section examination of the rock samples shows them to be composed of phenocrysts within a groundmass. The phenocrysts are 0.5-2.0mm in diameter, and grains of the groundmass are 0.05-0.1mm in diameter. Phenocrysts are mainly prism-shaped plagioclase crystals and quartz as well as smaller numbers of phenocrysts of hypersthene, biotite, and opaque minerals. Observation of opaque minerals using a reflecting microscope showed them to be comprised of ilmenite, magnetite, and a small amount of pyrite. Most of the groundmass is composed of globular-shaped quartz. Plagioclase has a large number of cracks compared with quartz. Many cracks were observed running along cleavages in the plagioclase, but in quartz phenocrysts cracks were seen to run in three directions along the axes of the crystals. No fractures were observed in the fine quartz crystals of the groundmass although many cracks run between mineral grains. In addition to these cracks, others run parallel to the surface of the rock and across cleavage planes at depths less than ca. 0.5mm, which may be called "micro-sheeting". Prism-shaped holes (the typical shape of crystals of plagioclasewere) observed on the rock surface. In places fragments of plagioclase were retained within the surface holes.

Observations by SEM suggest that the small-scale globular-shaped holes are 0.05-0.1mm in size and of similar shape and dimensions to the quartz groundmass. Other observations with SEM show very fine crystals, 0.001-0.01mm, adhering to the surface of the rock. When viewed under the optical microscope, the reddish brown material is seen to be amorphous and penetrate into cleavages, fractures, and the margins of certain crystals, particularly in case of hypersthene, ilmenite, and magnetite. This material also fills holes made by the loss of fine-grained quartz crystals from the surface. This material appears brown in thin section in reflected light.

2) X-ray diffraction analyses

The X-ray diffraction analyses (XRD) suggest that both the surface and interior of the rock consist of quartz, biotite, plagioclase (albite and anorthite), and hypersthene. The ratio of the strength of plagioclase and hypersthene to that of the quartz deep in the rock is high, whereas this same ratio on the rock surface is low. Clay minerals and salts were not detected by XRD.

3) Energy Dispersive Spectrometry (EDS)

EDS indicates that the surface of the rock includes Si, O, Al, K, Fe, and S. A crystal of hypersthene is comprised by Si, O, Fe, Mg, and Al, according to EDS. Reddish brown materials also present in a crack in a hypersthene crystal are composed of Si, O, Fe, Mg, and Al, but the EDS peak of Fe is more distinct than that of the enclosing crystal of hypersthene. In contrast, the very fine crystals on the rock surface identified by SEM are composed of Si, O, and Al, although some include Fe, K, and Ca. These elements suggest that the crystals are silicate minerals and not superficial salts.

Conclusions: Granular disintegration and microsheeting seems to have progressed by the cracking of minerals mainly due to thermal weathering. Because the thermal properties of quartz and plagioclase differ significantly, differential stress is created between these crystals, causing cracks between the crystals and along the cleavages of plagioclase. These processes allow plagioclase phenocrysts to fall out, such as through specific granular disintegration. The disintegration of plagioclase phenocrysts has left many prism-shaped holes, 0.5 to 2.0mm in length. Plagioclase and hypersthene, whose cleavages run in different directions, have fallen out in greater amounts than have quartz and biotite. Fine-grained quartz minerals (0.05 to 0.1mm), have fallen out in whole, uncracked crystals. Furthermore, because of the rapid changes in rock temperature in the polar regions, the cracks produce micro-sheets, or planes running parallel to the rock surface on the margin of the rock.

The rock wall is coated with a reddish brown (10R4/4) oxidized film 0.3-1.0mm in thickness that also coats some of the prism-shaped holes. The rock varnishes result from oxidation and consist of limonite, which fills cracks and penetrates into crystals. Ferrous iron in hypersthene, biotite, ilmenite, and magnetite is transformed into limonite by oxidation. Manganese is not found in the varnishes. Sulfur, which is important for oxidation and which may have originated from wind blow snow, is concentrated on the surface of the rock.

At the MPF Yogi site and in rocks from Antarctica, most of the mineral components are quartz and feldspars. It is still unknown if the MPF rocks are fully crystalline igneous or primarily groundmass. However, granodiorite porphyry will not only be exfoliated independent minerals, but andesite may also occur because some of the groundmass is exfoliated in the Antarctic rocks. The weight ratios of feldspars of MPF Yogi and Barnacle Bill sites [1] are much higher than Antarctic rocks. The feldspars have very high potential for granular disintegration and micro-sheeting. The Mars daily temperature fluctuations, which are much greater than inland Antarctica, also enhance thermal weathering. The thermal expansion properties of quartz and feldspars differ substantially therefore a stress is established between these materials.

The chemical compositions of the rock coatings are similar at the MPF and Antarctic sites. In both places, the surface coatings are not evenly distributed with respect to solar radiation, but appear to be more influenced by the dominant wind direction [2]. Sulfur rich coatings of the rocks were detected at the MPF [3] and Antarctic sites. Sulfur is an important component of these coatings. The source of sulfur in inland Antarctica would be from the upper troposphere or lower stratosphere, transported with snow. There are many sulfates of non-sea salt origin (exSO_4^{2}) in the wind blown snow at the Nolan Pillar. The coating process is more influenced by the wind direction than the solar radiation in both sites.

References: [1]R. Rieder et al., (1997) *Science, 278,* 1771–1774. [2]S. Murchie et al.,(1998) *LPS XXIX,* [3]N.T. Bridges et al., (1998) *LPS XXIX.* [4] T. Parker (1999) http://mpfwww.jpl.nasa.gov/MPF/mpf/high-res.html

Fig. 1 The surface coating distribution on the rocks at the Yogi site was uneven and had small pit holes [4].

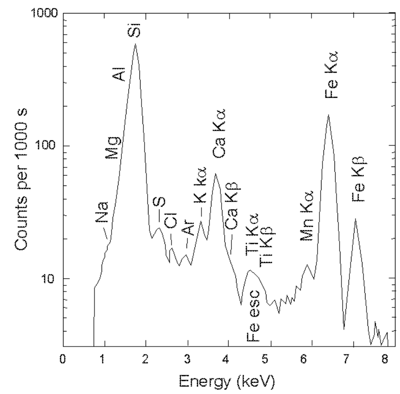

Fig. 2 X-ray spectrum of rock A-3, Barnacle Bill [1].

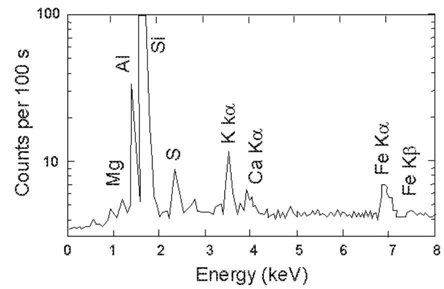

Fig. 3 Xray spectrum of Theil Mountain Rock, Inland Antarctica.

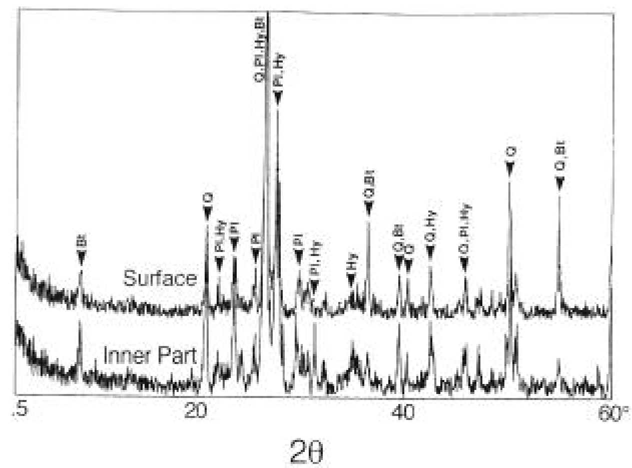

Fig. 4 X-ray diffractogram of the surface and interior of the rock described in Fig 3.

Fig. 5 Rock surface from the Nolan Pillar, Thiel Mountains. Many exfoliated holes were observed.