EVIDENCE FOR WEATHERING ON EARLY MARS FROM A COMPARISON WITH TERRESTRIAL WEATHERING PROFILES. A. Gaudin[1] and E. Dehouck[1] and N. Mangold [1] [1]Laboratoire de Planétologie et Géodynamique de Nantes, UMR 6112 CNRS/Université de Nantes, BP 92208, 44322 Nantes cedex 3, France, anne.gaudin@univ-nantes.fr.

Introduction: The surface of Mars displays widespread spectral signatures of alteration by liquid water in the ancient crust [1-3]. Al-bearing phyllosilicates (montmorillonite and kaolinite) on Mars are often detected using Near Infrared spectrometers in the vicinity of Fe/Mg smectites (nontronite and saponite) in regions such as Nili Fossae and Mawrth Vallis [4,5]. This relationship has been interpreted as being due to either (1) sedimentary deposition of materials of different provenance, (2) in situ alteration of materials with different initial composition (such as ash deposits and aqueous sediments), or (3) pedogenic weathering of the bedrock. Understanding whether or not the observed alteration is directly related to past climate is crucial for understanding the atmospheric conditions of early Mars. In this study, we show that the association between Fe/Mg smectites and Al-rich phyllosilicates observed at the Mars surface is similar to the weathering profiles of ultramafic terrestrial rocks. To illustrate this, we chosen to compare weathering profiles developed in serpentinized peridotites located at Murrin Murrin (MM) in Western Australia [6] with the Nili Fossae region located in the Northeastern hemisphere of Mars [7].

Results.

MM weathering profile. The weathering profiles developed in the MM serpentinite massifs have thicknesses of about 30–40 m and are composed of three main zones identified from bottom to top as saprolite, smectite zone and Al-rich zone (Fig. 1). The contact between each of these three zones is sharp and has a range of depths. The thickness of the smectite zone ranges between 10 and 20 m and that of the Al-rich zone between 5 and 15 m. These observations suggest that there were local variations in the intensity of weathering, which can be attributed to local changes in drainage conditions brought about by physical heterogeneities of the parent rock (crack density, porosity) and/or to an irregular topographic surface.

The saprolite zone is gray and massive with occasional meter-sized magnesite concretions. The mineralogy is dominated by serpentine with significant amounts of smectite. Traces of maghemite, opal, quartz, magnesite and dolomite minerals are also often found. The smectite zone has colors ranging from green to brown. Its mineralogy comprises smectite with a small quantity of maghemite. The Al-rich zone has an intense red color and an extremely friable structure. Its mineralogy is dominated by kaolinite and goethite with small amounts of smectite. Smectite minerals indicate a chemical evolution with depht. In the saprolite zone there are both Mg-rich smectites (saponite) and Fe–Mg-rich smectites. In the smectite zone the chemical-composition is relatively homogeneous, being rich in Fe with small amounts of Mg and Al. In the upper Al-rich zone, the smectites have an intermediate composition between the Al-rich end-member and the Fe-rich end-member with only a small amount of Mg.

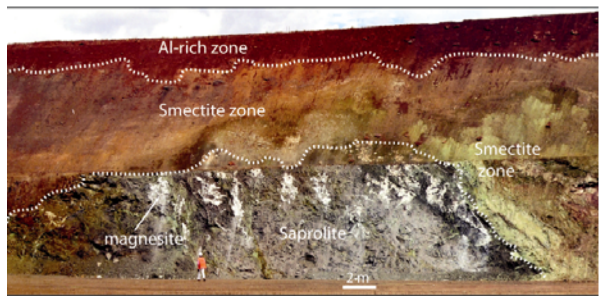

Fig. 1: MM weathering profiles developed in Archaean serpentinized peridotite massifs, which form part of the extensive Norseman–Wiluna Greenstone Belt located in the Eastern Yilgarn Craton (121º53’41’’E, 8º44’51’’S).

Nili Fossae. Our study area is located on the plateau west of the Nili Fossae trough, 900 m above the Nili Fossae floor, on the southeastern edge of a 50 km diameter crater (Fig. 2). A normal fault has tilted this block and its elevation is now 300 m below the main plateau. We extracted the mineralogy of the observed outcrops using CRISM data. Three groups of spectra were found. Firstly, we found spectra with 1.4, 1.9 and 2.2 µm absorption bands, which are typical of Al-bearing phyllosilicates. The asymmetry towards the short wavelength side of the 1.4 and 2.2 µm absorption bands indicates the presence of a kaolinite group mineral, such as kaolinite or halloysite, as previously identified in the Nili Fossae region [5]. Secondly, we observed spectra with 1.4, 1.9 and 2.3 µm absorption bands, which are indicative of the presence of Fe/Mg smectites [2]. We found spectra with a broad absorption band between 1 and 1.5 µm which is typical of olivine. The main units in the study area are shown on the map and 3D sketch. The kaolinite-bearing unit is present on the plateau above this location. A HRSC DEM cross section allows us to estimate the thickness of this unit to 20 m or less. The Fe/Mg smectites are found in a scarp stratigraphically below the kaolinite-bearing unit. Neither of these two units displays visible bedding typical of sedimentary deposits. Detailed examination of the olivine-bearing area reveals a small crater, which is filled by eolian deposits, around which the olivine-bearing material spreads out. This crater gives an upper limit to the overall thickness of the altered zone, strictly <80 m at this location, showing that the smectites are limited in thickness to several tens of meters.

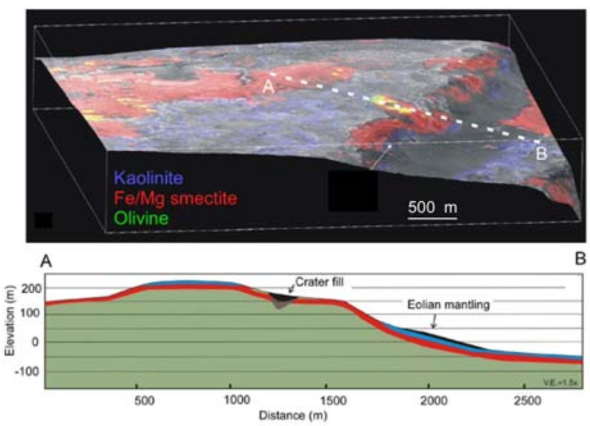

Fig. 2: 3D view of Nili plateau (centered 22°N, 74.6°E) based on CRISM RGB map superimposed over HRSC image 1347. The mineralogy was determined by using CRISM spectral data. The vertical exaggeration is 3X. A-B: Interpretative cross section using HRSC DEM topographic profile and composition as obtained at the surface.

Weathering conditions.

The weathering profiles described for Murrin Murrin, in Australia, appears to be a good analogue for the development of altered regions located stratigraphically above basic/ultrabasic bedrock on Mars. Both Murrin Murrin and our case study in Nili Fossae on Mars have a Fe/Mg smectite zone overlain by a zone composed of kaolinite and iron hydroxide minerals. The Murrin Murrin weathering profile demonstrates that a bedrock which is initially poor in Al can weather to Al-bearing phyllosilicates as a results of the intense leaching of Mg by the percolation of meteoric fluids. Hence, the superposition of Al-phyllosilicate horizons over Fe/Mg smectites on Mars, may indicate a widespread weathering process. At the Earth's surface, such weathering profiles are developed from ultrabasic rocks under past or present tropical climates [8-10]. Indeed, tropical climate induces (1) an intense hydrolysis process which results in the relatively large thickness of the profiles compared to those developed under less humid and/or colder climates, and (2) an efficient Mg^{2+} and S^{i4+} leaching by the percolating waters results in the appearance of the kaolinite zone at the top of the profile. Thus, the development of such profiles at the Mars surface could be the best evidence of past weathering as a direct result of a climate significantly warmer than the present one. Nevertheless, at the surface of Mars, the high hydrolysis and leaching could be explained by a more prolonged period of weathering under a less humid and warm climate. Indeed, contrary to the Earth's surface, the absence of major tectonic/erosion events on Mars allows processes to act on the surface over much longer timescales. Moreover, the presence of a primitive CO_2-rich atmosphere could have produced more acidic meteoric waters and therefore higher weathering rates than on Earth. Thus, a past elevated pCO2, coupled with a prolonged period of weathering, could be a significant factor in explaining the formation of thick weathering profiles on Mars despite the less humid conditions and colder temperatures than required to develop equivalent profiles on Earth.

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