INFERRING ALTERATION CONDITIONS ON MARS: INSIGHTS FROM NEAR-INFRARED SPECTRA OF BASALTS FROM SIBERIA AND EAST AFRICA. J. Gurgurewicz[1,2], D. Mège[1,3], V. Carrère[3], G. Cornen[3], A. Gaudin[3], J. Kostylew[4,5], Y. Morizet[3], P.G. Purcell[6], and L. Le Deit[7], [1]WROONA Group, Institute of Geological Sciences PAS, Research Centre in Wrocław, Podwale St. 75, PL-50449 Wrocław, Poland, [2]Space Research Centre PAS, Bartycka St. 18A, PL-00716 Warsaw, Poland (jgur@cbk.waw.pl), [3]Laboratoire de Planétologie et Géodynamique, UMR CNRS 6112, Université de Nantes, 2 rue de la Houssiniere, 44322 Nantes, France, [4]Institute of Geochemistry and Petrology, ETH Zürich, Clausiusstr. 25, 8092 Zürich, Switzerland, [5]Institute of Geological Sciences, University of Wrocław, Cybulskiego St. 30, PL-50205 Wrocław, Poland, [6]P&R Geological Consultants, 141 Hastings St., Scarborough WA 6019, Australia, [7]Institute of Planetary Research, German Aerospace Center (DLR), Rutherfordstr. 2, 12489 Berlin, Germany.

Introduction: Basaltic rocks are thought to be abundant at the surface of Mars. Evidence of basaltic surface composition comes from in situ chemical analysis [1, 2], characteristic absorption bands of olivines and pyroxenes, and mineralogical abundance modelling [3-6].

Of interest is whether information on the climate conditions prevailing during basalt alteration on Mars can be inferred from the measured basalt spectra. In order to address this issue, new spectral and chemical composition data of altered basalts in both arid cold and arid hot regions on Earth are compared to the Martian near-infrared spectra. The selected basalts are located in the Udokan area of Siberia, and in the Ogaden region of southeast Ethiopia (Figs. 1 and 2). They are all alkali basalts, Ti-rich, and have the same mineralogical structure.

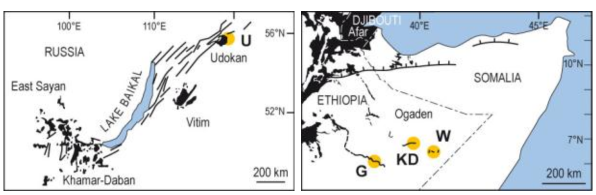

Figure 1 Location of the Cenozoic Udokan volcanic field and Ogaden basalts. The dark patches are the volcanic exposures. The sampling sites are shown by circles: U – Udokan volcanic field; G – north of Gode town; KD – east of Kebri Dehar town; W – south of the Werder town.

Figure 2 Altered lava flow from the Udokan volcanic field, and cobble from the Kebri Dehar flow of Ogaden.

Methods: The mineral composition and structure of the Udokan and Ogaden basalts have first been identified using polarizing microscope. Then the reflectance has been measured using the ASD FieldSpec® 3 spectrometer in the spectral range 0.35–2.5 µm, with 1 nm spectral resolution in the visible range and 3 nm in the infrared. Ninety-one spectra were acquired, both of the altered surface and internal part of the bulk samples, and of the whole-rock powders of grain size < 25 µm. Complementary information on composition of representative basalt samples have been retrieved from X-ray diffractometry, scanning electron microscope (SEM), and Micro-Raman spectroscopy.

Results and discussion: The studied basalts, despite their dramatic differences in alteration conditions, have very similar bulk rock spectra in the near-infrared (Figs. 3 and 4). Broad absorption bands in the bulk rock spectra, especially related to -OH and H_2O absorptions, make difficult recognition of smaller bands of critical importance in identifying some alteration minerals. The near-infrared spectra of the Martian bulk rocks are, therefore, unlikely to distinguish between basaltic rocks that were altered in arid hot or arid cold environments.

This study suggests that analyses of rock powders may help to discriminate between both environments. The rock powders altered in arid hot environment have a first-order positive spectral slope in the range 0.9–2.0 µm, whereas those altered in arid cold environment have a first-order negative spectral slope. This might help in evaluating different hypotheses of Martian paleoclimate conditions for surfaces having similar powder-size granulometry and optical properties.

Both the Ogaden and Udokan basalts display similar absorption at ~2.2 µm in bulk rock samples; in powders these environments produce different features. The Ogaden basalts keep their spectral signature, whereas the Udokan basalt powders show a more complex reflectance pattern in the range 2.17–2.22 µm. Its origin remains to be investigated; if similar features are observed in other basalts being weathered in arid cold environment, this pattern would provide an additional criterion for distinguishing between arid cold and arid hot climate in alteration conditions of Martian basaltic powders.

Two significantly different types of alteration observed in the Ogaden – surface oxidation associated with spheroidal weathering and penetrative weathering – cannot be distinguished either in the near-infrared bulk rock nor in the powder spectra (Figs. 4 and 5). This suggests that different processes of basalt alteration under a given climate might be difficult to distinguish in the near-infrared spectra of the Martian surface.

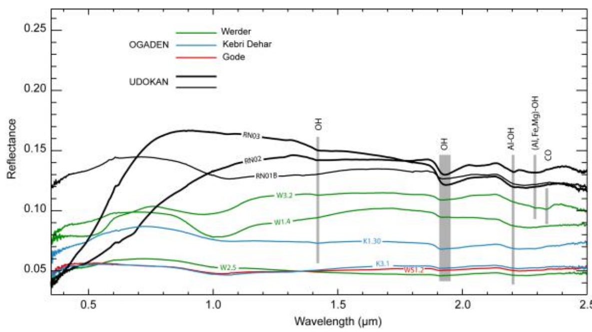

Figure 3 Near-infrared spectra of the Ogaden and Udokan fresh or nearly fresh rock surfaces. The spectra are nearly similar, apart from the missing ~1 µm absorption in two of the Udokan basalt spectra (bold lines).

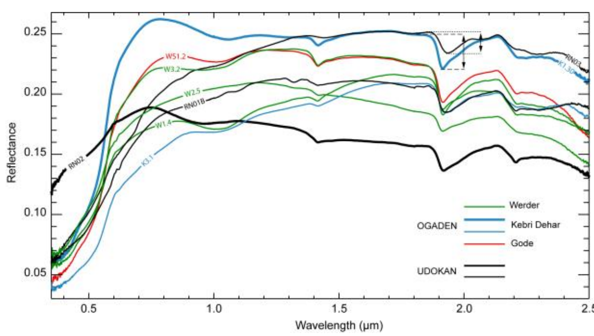

Figure 4 Near-infrared spectra of the Ogaden and Udokan altered basalt surfaces. Note the parallel spectra of the Udokan sample RN02 and Ogaden sample K1.30 in the range 0.7-2.5 µm (thicker lines), and the nearly identical spectra of the Udokan sample RN01B and Ogaden sample K3.1 in the range 1.9-2.4 µm. Water absorption at 1.9 µm is almost always stronger in the Ogaden than in the Udokan area (arrows).

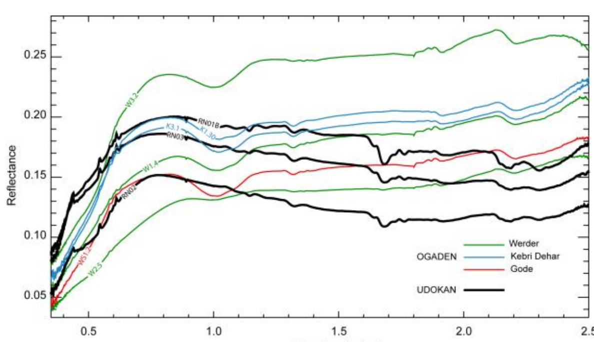

Figure 5 Near-infrared spectra of the Ogaden and Udokan basalt powders.

The Ogaden basalts are located in a much more arid setting than the Udokan basalts, but hydration bands are deeper in the Ogaden spectra than in the Udokan spectra (Fig. 4). Thus, an inverse correlation exists between rainfall and climate aridity, maybe related to the weathering effect of groundwater, or to the hydration state of the secondary minerals. Therefore, the deep hydration bands [e.g., 5, 7] observed on many Martian spectra of mafic mineral-rich areas [8] are not necessarily evidence of a past wet climate characterized by persistent water runoff during long-lasting wet seasons. They are also consistent with dry conditions, cold or hot, with only very limited or no precipitation.

Conclusions and perspectives: Interpreting alteration environments using near-infrared spectra requires: (1) analysis of the rock powders; (2) complementary studies using other techniques.

Part of the weathering of Icelandic basalts has been shown to have a biogenic origin [9-11]. Understanding the basalt alteration on Mars requires therefore the understanding of the influence, if any, of the biological (fungi) communities on the near-infrared spectra of altered basalts. If they do have any influence, comparison between spectral features on Earth and Mars may either be biased, or, if the signature of fungi can be identified and diagnostic, reveal the evidence for biogenic alteration of Martian basalts.

References: [1] McSween H. Y. et al. (2004) *Science*, *305*, 842–845. [2] Bell J. F. III et al. (2002) *Icarus*, *158*, 56–71. [3] Salvatore M. R. et al. (2010) *JGR*, *115*, E07005. [4] Bibring J.-P. et al. (2005) *Science*, *307*, 1576–1581. [5] Mustard J. F. et al. (2008) *Nature*, *454*, 305–309. [6] Poulet F. et al. (2009) *Icarus*, *201*, 69–83. [7] Bishop J. L. (2008) *Science*, *321*, 830–833. [8] Mustard J. F. et al. (2005) *Science*, *307*, 1594–1597. [9] Etienne S. (2002) *Geomorphology*, *47*, 75–86. [10] Etienne S. and Dupont J. (2002) *Earth Surf. Process. Landforms*, *27*, 737–748. [11] Viles H. A. (2008) *Geogr. Compass*, *2/3*, 899–919.