REFLECTANCE SPECTRA OF LISTVENITES: LOW-TEMPERATURE CARBONATE-SILICA-RICH ALTERATION PRODUCTS OF MAFIC SILICATES. E. A. Cloutis[1], N. N. Turenne[1], D. M. Applin[1], A. Beinlich[2], and D. Mége[3]. [1]Centre for Terrestrial and Planetary Exploration, University of Winnipeg, 515 Portage Avenue, Winnipeg, MB, Canada R3B 29; e.cloutis@uwinnipeg.ca). [2]Physics of Geological Processes, University of Oslo, P.O. Box 1048 Blindern, 0316 Oslo, Norway. [3]Centrum Badań Kosmicznych Polskiej Akademii Nauk (CBK PAN), Warszawa, Poland.

Introduction: Listvenite (aka liswanite, listvanite, listwaenite) is a rock derived from intense alteration of ultramafic rocks such as peridotite by CO_2-rich fluids at generally low temperatures (50-200°C) [1,4]. It forms in two successive stages: auto-metasomatic serpentinization and metasomatic overprinting. Consequently, listvenites may preserve evidence of the protolith and subsequently formed serpentinite. Listvenite is characterized by the presence of abundant or exclusively carbonate and silica. Subtypes are based on the carbonate:silica ratio and type of carbonate [2]

Listvenite is common in the Semail Ophiolite in Oman [1], and present in a number of other localities, such as the Solund basin in Norway [3], and near Atlin, BC, Canada [4,5]. Listvenite has been suggested as being present on Mars in the Ladon basin on the basis of spectroscopic data and geomorphology [6].

To better understand the remote sensing detectability of listvenite in terms of its mineralogy and mineralogic and petrologic diversity, we are undertaking a comprehensive study of listvenites using multiple analytical techniques. Here we report of preliminary analysis of samples from the Pictou mine near Atlin.

Methods: Preliminary results for one of two sawcut slabs of listvenite from the Pictou mine are presented. The sample shows a mottled white-gray-brown appearance (Figure 1).The sample has been characterized by reflectance spectroscopy and X-ray diffractometry..

Visible and near-infrared reflectance spectra of selected spots on the slab were collected with an ASD LabSpec4 Hi-Res® spectrometer (350-2500 nm) at i=30°, e=0°, and 500 averaged scans.

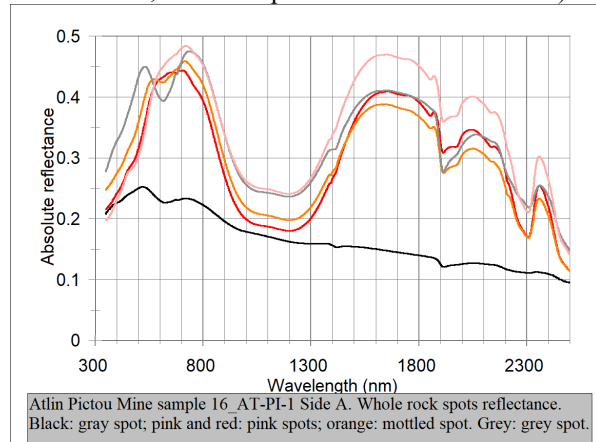X-ray diffraction analysis of a powdered <45 µm subsample was conducted in continuous scan mode from 5° to 80° 2θ using a Bruker D8 Advance powder X-Ray Diffractometer with a DaVinci automated powder diffractometer. A Bragg–Brentano goniometer with a theta-theta setup was equipped with a 2.5° incident Soller slit, 1.0 mm divergence slit, a 2.0mm scatter slit, a 0.2mm receiving slit, a curved secondary graphite monochromator, and a scintillation counter collecting at an increment of 0.02° and integration time of 10 s per step. The line focus Co X-ray tube was operated at 40 kV and 40 mA, using a take-off angle of 6°. Minerals were identified using Bruker EVA pattern analysis software and the Crystallography Open Database [7].
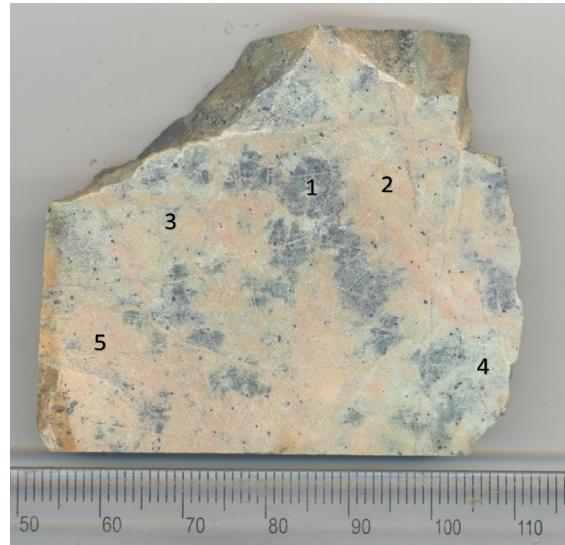
Figure 1. The Atlin listvenite sample (cm scale bar).

Results: X-ray diffractometry of the sample indicated the presence of quartz, dolomite, and magnesite.

The reflectance spectra are shown in Figure 2. The different spot spectra show similarities and differences. All show a broad doublet near 1000 and 1200 nm, a weak 1410 nm OH band, and a doublet carbonate-associated feature centered near 2310 nm. The gray and white spot spectra (#1, 4) also show an absorption band near 610 nm. These two spots also show a singlet-like absorption band near 1910 nm, while the other spot spectra show a doublet in this region (near 1910 and 1980 nm, and a sharp weak band near 1860 nm).

Atlin Pictou Mine sample 16_AT-PI-1 Side A. Whole rock spots reflectance. Black: gray spot; pink and red: pink spots; orange: mottled spot. Grey: grey spot.

Figure 2. Reflectance spectra of spots in Fig. 1.

Discussion: The downturn in reflectance below ~580 nm and kink near 470 nm is likely attributable to Fe oxyhydroxides. The absorption feature seen near 610 nm is likely attributable to either Ni [9] or Cr [10, 11], as both can be concentrated in listvenites [8], commonly as the Cr-mica fuchsite ($K(Al,Cr)_2(AlSi_3O_{10})(OH)_2$. Fuchsite is a bright green mineral and is present at the Pictou mine site but is not visually evident in this sample. Other Ni- and Cr-bearing phases can also occur [12].

Fe^{2+}, substituting for Mg in dolomite or magnesite accounts for the 1000/1200 nm doublet [13]. The 1410, 1860, and 1910-1980 nm region bands are likely attributable to OH/H_2O. However, the phases detected by XRD should not exhibit absorption bands in this region, as they are all nominally anhydrous (Figure 3). We believe that these features are attributable to OH/H_2O in various forms, such as fluid inclusions, or minor hydrated phases that are not detectable by XRD, such as fuchsite [11].
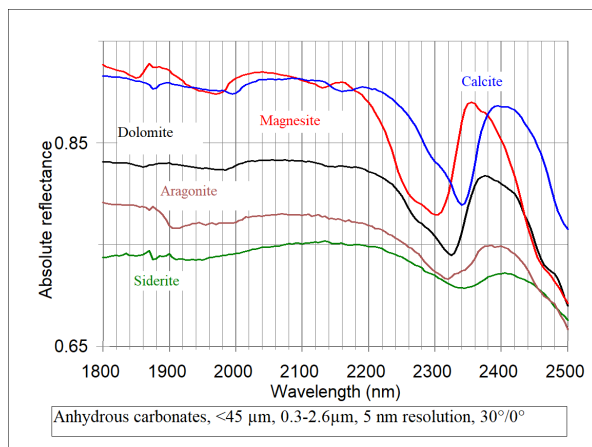

Figure 3. Reflectance spectra of various carbonates.

The position of the 2300 nm region absorption band (near 2310 nm) is consistent with both magnesite and dolomite [14], in agreement with the XRD results. Quartz would be expected to exhibit an Si-OH absorption band in the 2210-2260 nm region. There is weak evidence for it in two of the spectra but this feature, if present, is difficult to recognize because it is superimposed on the short wavelength wing of the 2320 nm carbonate feature.

Listvenite spectral summary: The listvenite spectra are dominated by absorption bands that can be attributed to specific minerals and cations. In particular, the 610 nm absorption band is likely attributable to Cr (likely present as fuchsite). The 900-1500 nm region is dominated by Fe^{2+} in the carbonates. The relevance of the 1900 nm absorption feature is not fully known, but is attributable to OH/H_2O, perhaps in a number of

forms. The position of the carbonate band in the 2320 nm region can be used to constrain the type of carbonate that is present – both magnesite and dolomite have an absorption band at 2310-2320 nm (Figure 3). Quartz, which is present in the sample, is not readily detectable in the spectra.

Implications for Mars: Our field observations at the Pictou mine site found that the listvenite outcrop is mineralogically and petrologically heterogeneous at cm to m scale and had an overall appearance of stockworks. Green fuchsite was variably distributed across the outcrop, usually occurring at cm to tens of cm scale. The degree of alteration at the site also correlated with its hardness. The most altered part of the outcrop, where serpentinite was not present correlated with increased hardness, so that the highest standing parts of the outcrop were the whitest and contained the least amount of residual mafic materials. This is consistent with the suggestion of listvenite dominating high-standing outcrops in the Ladon basin [6].

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