

NEAR-INFRARED SPECTRAL DIVERSITY OF THE FERRAR DOLERITE IN BEACON VALLEY, ANTARCTICA: IMPLICATIONS FOR MARTIAN CLIMATE & SURFACE COMPOSITIONS. M. R. Salvatore¹, M. B. Wyatt¹, J. F. Mustard¹, J. W. Head¹, & D. R. Marchant², ¹Brown University, Dept. of Geological Sciences, 324 Brook St., Box 1846, Providence, RI 02912, Mark_Salvatore@brown.edu, ²Boston University, Dept. of Earth Sciences, Boston, MA 02215.

Introduction: The Antarctic Dry Valleys (ADV) are a hyper-arid, cold polar desert and represent some of the oldest and most stable land surfaces on Earth [1]. Three microclimate zones within the ADV have been identified based on differences in elevation, temperature and precipitation [2]: the Stable Upland Zone (SUZ), Inland Mixed Zone (IMZ), and Coastal Thaw Zone (CTZ). The SUZ is the coldest (mean annual temperature of -22°C) and driest (mean annual relative humidity of 43%) of the ADV microclimate zones and is thus the most Mars-like [3].

The type example of the SUZ is Beacon Valley, located in the Quartermain Mountains between the East Antarctic Ice Sheet to the south and Taylor Glacier to the north. The floor of Beacon Valley is dominated by material derived from sills of the Ferrar Dolerite group [4,5], which is compositionally analogous to the martian surface [6] and basaltic martian meteorites [7].

The climate conditions and surface compositions present in Beacon Valley are thus ideal for Earth-Mars analog studies. The focus of this study is to characterize the near-infrared (NIR) spectral diversity of alteration minerals present on Beacon Valley doleritic surfaces and soils. The results are then interpreted as an analog to aqueous surface alteration on Mars.

Geologic Setting: The bedrock lithologies of Beacon Valley consists of Triassic-age sedimentary rocks of the Beacon Supergroup that are extensively intruded by Jurassic-aged doleritic sills [4,5]. Despite this diversity of bedrock lithologies, the floor of Beacon Valley is dominated by a stable regolith of old doleritic clasts. The presence of sublimation polygons [8], pitting on fine-grained dolerite surfaces [9], and the presence of undisturbed 8.1 Myr-old ash deposits [10] indicate the floor of Beacon Valley has experienced cold, stable conditions for millions of years.

Methods: Data were acquired during the 2009-2010 ADV field season with the support of the National Science Foundation and the United States Antarctic Program. Dolerite rock and soil samples were collected in central Beacon Valley and NIR spectra were acquired in situ using an ASD field spectrometer. Measurements of broken rock interiors, natural rock surfaces, and doleritic soils were made using a contact probe to better constrain initial compositions and the shape and magnitude of alteration features while minimizing atmospheric effects. White reference and dark current measurements were made prior to each measurement to calibrate radiance to reflectance.

Results: NIR spectra of broken rock interiors were measured to constrain the intrinsic spectral characteristics and petrologic diversity of the Ferrar Dolerite. Natural rock surfaces were measured to understand the extent of surface alteration and its relationship to rock interiors. Spectra of doleritic soils were also obtained for comparison to spectra of dolerite rock surfaces.

Broken Dolerite Rock Interiors. NIR spectra of dolerite interiors (Fig. 1, dashed lines) indicate relatively homogenous compositions. Prominent features include the presence of a strong, broad pyroxene crystal field absorption feature centered near 1 μm . Narrow absorption features near 1.9 and 1.4 μm are due to the presence of H_2O and $\text{H}_2\text{O} + \text{OH}$, respectively, and indicate the presence of smectite clay and/or phyllosilicates. These minerals may be the result of deuteric alteration of the Ferrar Dolerite [11]. The 2 μm pyroxene feature is not well defined because it is modulated by the presence of phyllosilicate spectral features.

Natural Dolerite Rock Surfaces. NIR spectra of exposed dolerite surfaces (Fig. 1, solid lines) show the presence of oxidation minerals as well as stronger phyllosilicate absorptions relative to their interiors. These observations suggest a greater extent of alteration on dolerite exteriors compared to their interiors, although spectral effects due to surface roughness and multiple scattering cannot be ruled out. A reddening of rock surfaces is apparent by the sharp increase in reflectance between 0.50 μm and 0.70 μm relative to broken interior spectra. The rounded reflectance maximum near 0.74 μm and minima near 0.54 and 0.91 μm are indicative of the presence of iron oxides, likely from the leaching of iron from dolerite interiors [12]. Water and hydroxyl absorption features with band centers at 1.91 and 1.42 μm are stronger than observed in the broken rock interiors. The 1.9 μm band depth was calculated using the BD1900R parameter originally developed for the CRISM orbital spectrometer on MRO [13]. Broken rock interiors have an average 1.9 μm band depth of 0.0365 while natural rock surfaces have an average band depth of 0.0707, nearly double that of the broken rock interiors. Shallow absorption features are also visible in spectra of natural rock surfaces at 2.20 and 2.29 μm , indicating the presence of a variety of smectite clays and phyllosilicates that are also observed in prior studies [11]. Additional NIR laboratory measurements will be acquired upon completion of ongoing field work to constrain these absorption features and determine the exact alteration minerals present.

We observe spectral variations associated with alteration coatings on dolerites as a function of the orientation of rocks within Beacon Valley (Fig. 2). Alteration coatings on north-facing sides of dolerites are more mature than those on south-facing sides, likely due to the scouring of south-facing surfaces by katabatic winds coming off the East Antarctic Ice Sheet [12]. These strong southerly winds would thus prevent the development of mature alteration coatings and reveal relatively fresh doleritic material, as is evident in the NIR spectra (Fig. 2). These observations have implications for orbital reflectance spectroscopy of Beacon Valley and other planetary surfaces; different illumination angles can reveal variations in the development and maturity of alteration due to climatic processes.

Dolerite Surface Soils. Dolerite surface soils (upper 1 cm) from central Beacon Valley show subtle spectral variations. Compared to rock spectra, soils (Fig. 1, solid grey spectrum) have a significantly higher albedo in addition to deeper absorption features due to the presence of alteration minerals. While textural properties likely influence the NIR spectra of soils, the overall spectral shape and observed position of absorption features for doleritic soils are similar to natural dolerite rock surfaces.

Summary and Implications for Mars: NIR field spectra of dolerites in Beacon Valley reveal variations in the type and extent of alteration minerals produced in one of the coldest and driest environments on Earth. OMEGA and CRISM observations also reveal a wide diversity of aqueously derived minerals on Mars (e.g., phyllosilicates, sulfates, & hydrated silica). Upon completion of the ongoing 2009-2010 ADV field season, NIR laboratory spectra of the collected samples will be measured to determine the exact compositions of hydrated minerals for comparisons to those detected in martian orbital spectroscopy. These comparisons can be used to further understand potential martian environmental conditions (how warm and how wet?) and the extent and origin of chemical weathering on Mars.

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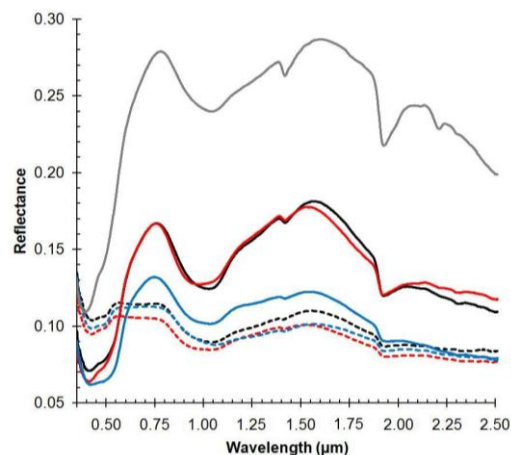


Fig. 1. NIR spectra of the interiors (dotted lines) and exteriors (solid lines) of 3 doleritic rocks (black, red, & blue) from Beacon Valley. Grey spectrum is a typical doleritic soil.

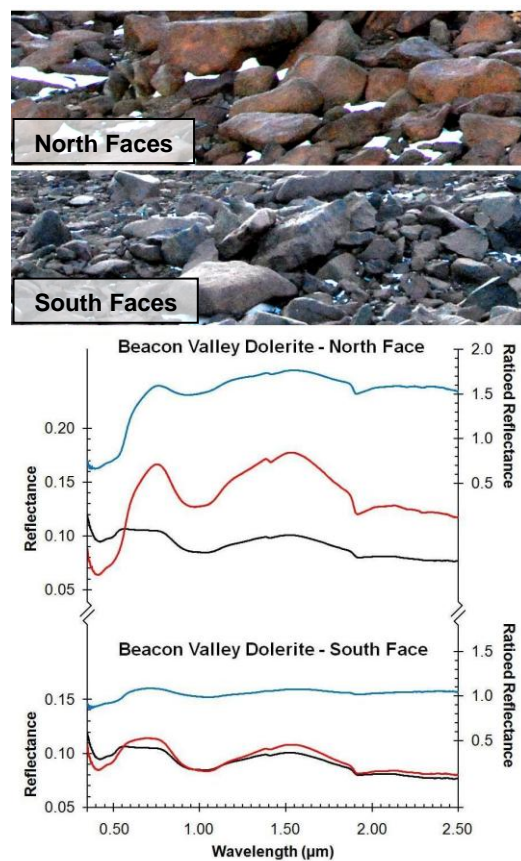


Fig. 2. NIR spectra of north and south faces of a representative dolerite from central Beacon Valley. Black spectra = broken rock interior, Red spectra = natural rock exterior, Blue spectra = ratios of natural exterior to broken rock interior. Photos were taken at the same time of day, from the same vantage point, and in opposite directions. Photos are approximately 5 meters across.