DEVELOPMENT OF ALTERATION RINDS ON THE FERRAR DOLERITE OF THE ANTARCTIC DRY VALLEYS: INITIAL CHARACTERIZATION. M. R. Salvatore, M. B. Wyatt, J. F. Mustard, and J. W. Head III, Brown University, Dept. of Geological Sciences, 324 Brook Street, Box 1846, Providence, RI 02912, Mark_Salvatore@brown.edu.

Introduction: The formation of alteration rinds on the Ferrar Dolerite lithologies exposed in the Antarctic Dry Valleys (ADV), one of the coldest and driest places on Earth, is important for understanding chemical alteration processes in this extreme environment and has implications for martian weathering processes. Significant variability is observed in these rinds that is potentially moderated by morphological, chemical, and mineralogical variations in the primary lithology.

Previous analyses of Antarctic dolerites characterized the range in chemistry and mineralogy of their interiors [e.g., 1, 2] and the chemical characteristics and variability in alteration rinds [e.g., 3, 4]. With regards to dolerite alteration, these studies have identified the role of liquid water in the formation of etch pits and secondary minerals [3] as well as variations in chemistry with depth [4], yet no previous work has linked the exterior and interior rock mineralogies and chemistries with the processes by which alteration occurs. Following from these fundamental analyses, several outstanding questions remain: What are the underlying processes that lead to the development and maturation of surface alteration in Ferrar Dolerites? What leads to variations in rind thickness and character (e.g., chemical/mineralogical variability within the dolerite suite, climate variability, etc.)? In this study, we aim to evaluate the diversity in dolerite alteration rinds and compare this diversity with the chemical, mineralogical, and morphological properties of the rock interiors to better understand the fundamental processes that cause an alteration rind to develop on fresh dolerite surfaces. Here we examine the interiors and alteration rinds of three doleritic clasts using a range of analytical techniques. This characterization will aid in the formation of hypotheses regarding the mechanisms of alteration rind formation.

Methods: Optical and spectroscopic analyses are utilized to determine the morphology and mineralogy of the samples, while electron microprobe analyses constrain the chemical variability throughout the rocks. By limiting this study to a small geographic location in a well characterized climate regime, we hope to limit the number of external forcings that might hinder our ability to identify the underlying alteration pathway.

Samples: The three samples analyzed in this study were collected from central Beacon Valley in the Quartermain Mountains. This region is one of the coldest and driest locales in the ADV [5]. Previous studies have also shown that the floor of Beacon Valley is one of the most stable landscapes on Earth [6]. Our samples were selected based on their morphological diversity, the presence of well-developed alteration rinds (Fig. 1), and their apparent old surface exposure ages (i.e., smooth alteration rind and extensive pitting [5]). These characteristics ensure that alteration has proceeded to a sufficient degree and can be easily studied using various analytical techniques.

Sample #1 is a fine-grained, dark grey clast with an equigranular and matted texture. The rock exterior exhibits a glossy, red-brown alteration rind and extensive pits, some of which coalesce into connected troughs. The rind in the bottom of these pits is more red-orange than the glossy rind found on the remainder of the rock. Despite the apparent extent of alteration, the rind is extremely thin and discoloration is visible to a depth of less than 1 mm below the rind.

Sample #2 exhibits a porphyritic texture with black orthopyroxene phenocrysts up to 1 mm in diameter set in a lighter grey aphanitic groundmass. The red-brown alteration rind is rougher and duller than that of sample #1. Small (< 5 mm diameter) pits are present on the rock surface in a random pattern and show no distinct difference in alteration relative to the surrounding rind. Below the thin alteration rind is a zone of discoloration roughly 5 mm deep and grades from the underlying grey groundmass into the red-brown alteration rind.

Sample #3 displays a phaneritic, coarser grained texture than the previous two samples. The rock interior contains a variety of grain sizes creating a mottled texture. The alteration rind is well developed, red-brown in color, and rougher and more undulatory

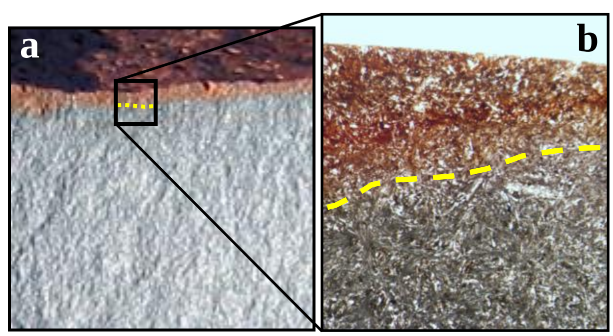

Fig. 1. (a) A photograph of sample #2 showing a clear discoloration with depth into the interior. Image width is 4.9 cm. (b) A thin section showing the alteration zone of sample #2. Image width is 3.3 mm. The base of the discolored zone is labeled in both images with a yellow dashed line.

than the finer grained samples. In addition, the zone of discoloration beneath the alteration rind extends roughly 10 mm into the rock interior, apparently replacing the medium and dark grey grains with a red-brown altered material.

These three rocks provide the diversity of interior properties and apparent thickness of alteration that we will further characterize in this study.

Current Analyses & Rationale:

VIS/NIR Reflectance Spectroscopy. This technique distinguishes major ferrous silicates, ferric oxides, and hydrated mineralogies using reflected light. Preliminary analyses reveal that alteration rinds inherit many spectroscopic features present in the rock interiors (Fig. 2). The red-brown appearance of the alteration rinds is defined by low reflectance from 0.4 – 0.55 μm and a steep increase in reflectance near 0.60 μm. Beyond the wavelengths of visible light, the altered rock surfaces have a systematically higher albedo than their respective interiors. However, there are no additional unique spectral features obvious in the altered rock surfaces.

Thermal Emission Spectroscopy. Emission spectra of these samples are currently being obtained to further constrain surface and interior mineralogies as well as to estimate modal mineralogies using linear deconvolution techniques. Previous studies [7] have shown that thermal emission spectra of dolerite exteriors and interiors can be extremely different, indicating an increase in silica-rich glass and alteration products in the alteration rind relative to the rock interior. However, significant spectral heterogeneities have been found amongst dolerites that may result from variations in the climatic regime to which the rock has been exposed. By holding the geographic and climatic setting of our samples constant, we hope to disconnect the spectral variations caused by these external forcings from the inherent variability caused by the alteration process and the underlying properties of the rock interiors.

Electron Microprobe Analyses. Sample analyses are currently being performed to assess the chemical variations observed along the traverse from the rock interior to the alteration rind. Previous studies [3] of a single altered dolerite indicate that Fe concentrations increase by more than 24% in the altered surface relative to the rock interior, while Si concentrations decrease by greater than 7%. This observation is inconsistent with the thermal emission spectroscopy results presented by [7] and indicates chemical heterogeneity amongst altered dolerites in Antarctica. Therefore, analyzing chemical variations with depth using electron microprobe analyses and relating these measurements to the observed reflectance and emission spectra of the same rocks and surfaces will help to understand the fundamental alteration processes at work in Beacon Valley.

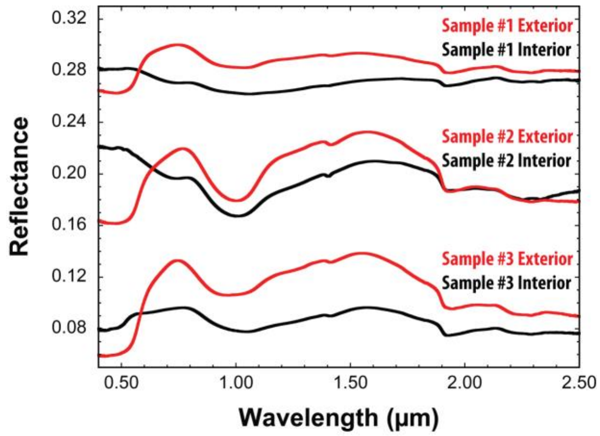

Fig. 2. Near-infrared reflectance spectra of the interiors and exteriors of the rock samples. The red appearance of the alteration rinds is apparent in the spectra in addition to their overall higher albedo in the near-infrared. Sample #1 spectra are offset by +0.2, sample #2 spectra are offset by +0.1, and sample #3 spectra are offset by +0.0.

Preliminary Conclusions: Thus far, our analyses clearly show the relationship between rock interiors and exterior alteration products (e.g., Fig. 2). In addition, when compared to previous studies, our work emphasizes the amount of variability seen in previous analyses of dolerites from throughout the ADV.

The analyses put forth in this study are designed to better understand the process of rock alteration in cold and dry environments. The chemical, mineralogical, and morphological transition from an unaltered to an altered surface holds valuable information regarding the regional landscape and environmental history under which the alteration processes occurred. Developing a clear understanding of these alteration pathways will allow for future studies to address questions regarding the rate of alteration, and whether the alteration process plateaus after a certain extent, among many others. It is our objective to gather the chemical, mineralogical, and morphological data necessary to identify the alteration products and to understand and interpret the alteration process on Earth and Mars.

References: [1] Marsh, B (2004) *Eos*, *85*, 497-502. [2] Bédard J. H. et al. (2007) *J. Petrol.*, *48*, 2289-2326. [3] Allen C. C. and Conca J. L. (1991) *Proc. Lunar & Planet. Sci.*, *21*, 711-717. [4] Chevrier V. et al. (2006) *EPSL*, *244*, 501-514. [5] Marchant D. R. and Head J. W. (2007) *Icarus*, *192*, 187-222. [6] Sugden D. E. et al. (1995) *Nature*, *376*, 412-414. [7] Wyatt M. B. et al. (2008) *LPSC XXXIX*, abs. 2105.