

SPECTROSCOPIC AND GEOCHEMICAL ANALYSES OF SEDIMENTS FROM LAKE HOARE, ANTARCTICA AND APPLICATIONS TO DRY VALLEYS ON MARS; *Janice L. Bishop*¹, *Peter A. J. Englert*², *David W. Andersen*², *Claudia Kralik*³, *Christian Koeberl*³, *Carlé M. Pieters*¹, *Heinz Froeschl*⁴ and *Robert A. Wharton, Jr.*⁵. ¹Brown University, Providence, RI; ²San Jose State University, San Jose, CA; ³Institute for Geochemistry, University of Vienna, Vienna, Austria; ⁴Universität für Bodenkultur, Vienna, Austria; ⁵Desert Research Institute, University of Nevada, Reno, NV.

The sedimentary records from ice-covered lakes in the Antarctic dry valleys may provide information about sedimentation in the dry valley regions on Mars, where ice-covered lakes may have existed in the past. Antarctic lake bottom sediments have been examined using reflectance spectroscopy and neutron activation analysis to study sedimentation processes in the dry valleys. Sediment cores were sampled from three locations (two aerobic, one anaerobic) in Lake Hoare, a perennially ice-covered lake in the Taylor Valley (77 °S, 162 °E). Organic material was found at the surface of each core. Thin layers of organic and carbonate-rich mats were also found dispersed throughout the cores. The core sediments are comprised of quartz, feldspar, polycrystalline rock fragments and monocrystalline accessory minerals. Na/K ratios and Sc concentrations are nearly constant for all of the samples measured. Variations in the Fe, Zn and Sr levels indicate non-uniform sedimentation processes. Quartz, pyroxenes, clays, carbonates and organic materials have been identified in the sediments from reflectance spectra. The reflectance spectra indicate diversity in the dominant mineralogy as a function of depth in the cores. Variation in the quartz grain size is also observed throughout the cores; organic-rich layers have very fine quartz particles and other sand layers have quartz grain sizes on the order of 100 µm or larger.

Introduction. Perennially ice-covered lakes exhibit important differences from non-ice-covered lakes, such as the presence of coarse sand in the center of the lake[1]. Studying lake bottom samples from the dry valleys in Antarctica provides information about sedimentation that may be relevant to understanding soils on Mars. Geophysical evidence on the surface of Mars indicates the presence of water there at one time[2]. Ice-covered lakes may have formed as the planet cooled and sediments exposed from these lakes may be contributing to the current surface material on Mars. The sedimentary record also bears information about former climates on Earth and thus, understanding sedimentary records for Mars-like lakes in Antarctica might lead to climatic information about Mars as well[3].

Sedimentation patterns developed for Lake Hoare, Taylor Valley, Antarctica, are based on mineralogical and grain size analyses of sediment cores from the lake bottom and of material collected in sediment traps in the lake, as well as on observations of sediments in the ice sheet[1,4,5]. These studies suggest that the lake bottom sediments are similar to the sediment found on top of the ice cover and the dominant means of transport is via sediment percolation from meltwater pools. Fine-grained sediment and organic material is thought to deposit slowly and continuously across the lake bottom. Sudden and localized deposition of coarser-sized sediment occurs through cracks in the ice or bubble channels.

The samples employed in these studies were collected in cores from aerobic (DH-1, DH-2) and anaerobic (DH-4) regions of the lake. The locations of these dive holes are described in[1]. The frozen cores were carefully melted and separated by sediment layers. Organic mat layers were found near the top of each core. Some cores contained organics intermixed with sediments at depth as well. The sediments from the aerobic lake regions are cream to tan colored, while those from the anaerobic region are a darker gray-green color.

Grain Size and Mineralogy. The sediments range from fine- to coarse-grained sand that is subquartzose with variable mineral contents. An average sample contains roughly equal amounts of quartz, feldspar, polycrystalline rock fragments (mostly felsic plutonic rocks with lesser amounts of mafic volcanics and metamorphic rocks), and monocrystalline accessory minerals (mostly orthopyroxene and clinopyroxene with variable amounts of biotite, chlorite, olivine and hornblende). The rock fragment percentage increases with increasing grain size, while the abundance of the accessories decreases with increasing grain size.

Some samples contain both sand and microbial mat. These samples have organic matter and biogenic carbonate with varying amounts of terrigenous sediment. Sand within the mat layers resembles the sand samples described above. Suspended silt and clay are most abundant in samples with the highest organic-matter content, suggesting slow sediment accumulation rates for these samples[1].

Geochemistry. A preliminary study of another DH-2 core showed variability in some major and minor elements throughout the core[6]. The elements Al, Sc, Fe, Zn and Cu exhibit variable concentrations in Antarctic lakes due to precipitation out of the lake water into the sediment and other processes taking place at the sediment-water interface[7]. In the cores examined here Sc levels remain constant near 20 ppm, and Fe and Zn concentrations vary by about a factor of two, but tend to parallel each other.

Snow contains small quantities of salts (Na⁺, Ca²⁺, Mg²⁺, K⁺, Cl⁻ and SO₄²⁻), which influence the salt composition of soils[8]. Salt fractionation is controlled by relative humidity and other properties of the salts, such that the least deliquescent salts will remain in the soil and the more deliquescent will percolate through the soil to the ice-cemented layer[8]. Analyses of Na, Ca, Mg, K, Cl and S in the cores are underway to assess whether these salts vary with either depth in the core or sediment grain size. Na/K ratios exhibit little variation within and among the cores examined in this study.

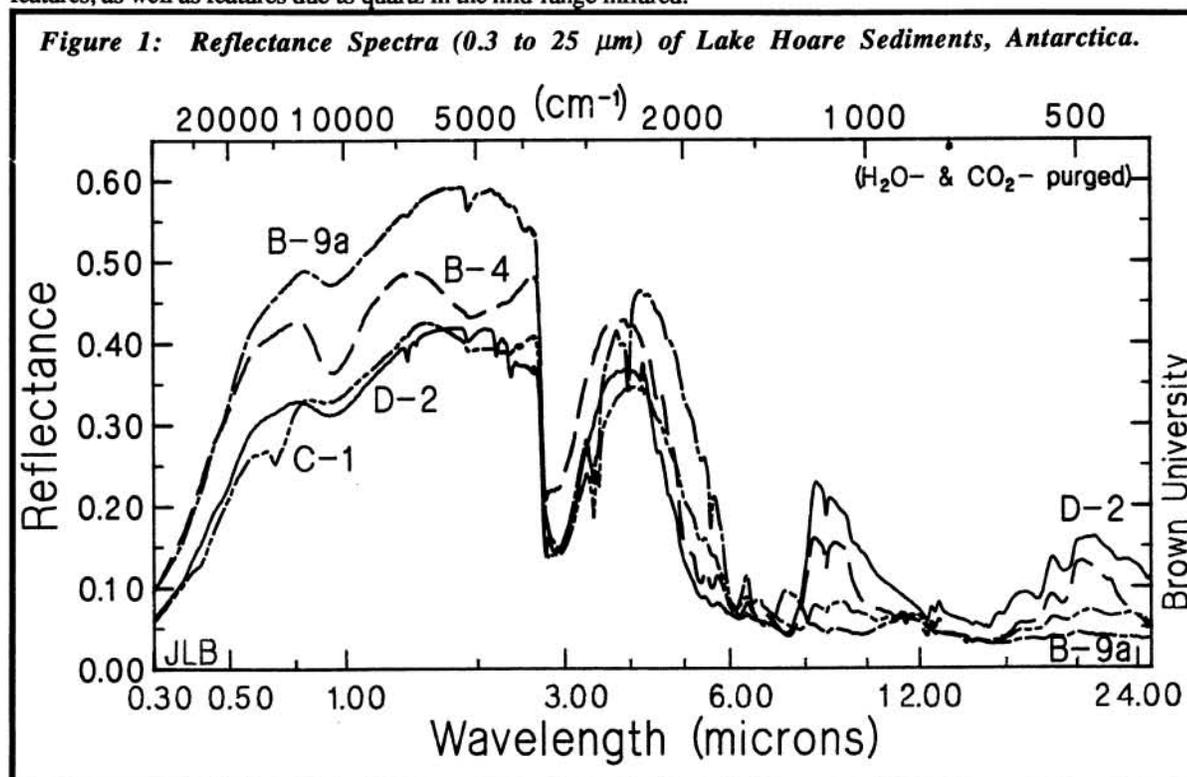
A decrease in Sr concentration was observed in water near the bottom of Lake Bonney (also located in the Taylor Valley), indicating precipitation of a Sr-bearing phase in the lake-bottom sediments[9]. Sr concentrations vary

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between 250 and 400 ppm in samples from core C (DH-4), and between 350 and 500 ppm in samples from core D (DH-1); however, core B (DH-2) shows a much broader range of Sr values including a high of 357 ppm in the surface sediment, a gradual decrease to a low of 11 ppm at 11-12 cm and a high of 326 ppm again at 28 cm depth. In core B the surface organic layer has only 75 ppm Sr, while some -1 mm thick organic layers have over 500 ppm Sr.

Reflectance Spectroscopy. Reflectance spectra indicate the presence of quartz, pyroxenes, clays, carbonates and organic materials in these sediments. Interpreting spectral data of soils is complicated because soils composed of multiple materials mix non-linearly and the spectral properties depend on the particle size distributions of the soil components and the manner in which the components are mixed in the soil, as well as the spectral properties of the individual components. Spectroscopic experiments involving mixtures of variable grain size separates of pyroxenes and olivine have shown that soils containing a higher abundance of small particles exhibit spectral properties dominated by the mineral having the small particle sizes; however, soils containing a higher abundance of larger particles exhibit spectral properties less directly related to one mineral [10,11].

Figure 1 includes reflectance spectra from 0.3 to 25 μm of samples B-4, B-9a, C-1 and D-2, which exhibit a number of different spectral features. The spectrum of sample B-4 includes strong pyroxene features in the near infrared at 1 μm and 2 μm , no indication of organic features at 3.4 μm or 6 μm and strong features due to quartz from 5 to 10 μm . Sample B-9a exhibits spectral features indicating a dominance of very fine-grained quartz and organics in the sediment, as well as smaller amounts of montmorillonite and carbonates. Many of the core C samples, from the anaerobic zone, show an absorption near 0.7 μm , which is similar to that found in vegetation. This is likely to be due to the algal mats observed dispersed throughout the core. This feature is most pronounced in the spectrum of sample C-1; also present in this spectrum are pyroxene features at 1 μm and 2 μm , strong organic features at 3.4 μm and 6 μm , and strong features due to fine-grained quartz from 5 to 10 μm . The spectrum of D-2 exhibits an absorption near 1 μm , but no absorption near 2 μm ; this spectrum also exhibits the strong near infrared montmorillonite and carbonate features, as well as features due to quartz in the mid-range infrared.



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