# DISCRIMINATING BASALTS USING THERMAL INFRARED

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Remote sensing of planetary surface composition is one of the primary objectives of the Mars Observer mission. The gamma-ray spectrometer and Thermal Emission Spectrometer (TES) are the principal experiments through which chemical and mineralogical data will be acquired. As part of a broad effort to prepare for interpretation of TES observations, we have begun a focused study of terrestrial basalts as a means of developing methods to discriminate subtle variations in native rock materials.

**Background.** Two different approaches have been taken in the present study. First, Thermal Infrared Mapping Spectrometer (TIMS) airborne observations of hawaiian lava flows have been examined to understand the effects of spatial and spectral resolution on the discrimination of composition. Abrams et al. [1] and Kahle et al. [2] report that the primary signature of thermal emission from basalt flow surfaces is not related to composition. Rather, they find that surface texture (aa *vs* pahoehoe), development and subsequent physical degradation of glassy crusts, and the development of surface veneers dominate the underlying petrological and chemical nature of the basalts. They note that these relationships develop over time, and are useful in discriminating age relationships. Our work has concentrated on comparing results at different spatial resolutions to determine the mixing effects of these surficial components, and to determine whether compositional information is discriminable as a function of resolution. The results of these studies will be reported elsewhere [3].

The second approach uses laboratory thermal spectroscopy to explore the relationships of spectral and spatial resolution on a microscale. Such studies may be analogous to the larger-scale mixing seen both in the airborne observations, and those to be seen in TES data, by presenting within a given field-of-view several components of different compositions and textures (e.g., grain size).

**Approach.** Two infrared laboratory instruments were used in this study. A Mattson infrared spectrometer (emission between 6 and 40 μm) and a Spectra-Tech infrared microscope (transmission between 13 and 25 μm) were used to acquire spectra of whole rock, phenocryst, and groundmass samples. Additionally, an electron microprobe was used to determine the elemental composition of these samples.

Each sample material was examined in three different configurations. Whole rock spectra were acquired of samples several cm across--these samples included basalt "unknowns" and monomineralic standard specimens of representative constituent minerals. The field-of-view of observations was about 2 cm. Single crystals were examined with the IR microscope, whose field of view covered approximately 100 μm. Standard thin sections were used for both petrographic microscopic study and electron microprobe elemental analysis.

**Results.** We focus here on a single basalt specimen, collected in north central Iceland in 1985, and standards representing the range in composition of its primary phenocryst, feldspar. In hand sample, the basalt is nearly 30% feldspar, 10% vesicle, and 60% groundmass (mostly feldspar and olivine glass).

The results of the first experiment, comparing the emission spectrum of the whole rock with the transmission spectra of single crystal plagioclase and olivine phenocrysts and groundmass, are shown in Figure 1. Also shown is a linear combination of the transmission spectra which is the closest fit to the whole rock spectra (plagioclaise:30%, olivine:20%, ground mass:50%). The effects of surface morphology of the whole rock (particle size, the vesicles, etc.) are not accounted for in the combination spectra. These effects combined with the groundmass signature appear to dominate the whole-rock spectra.

We next approach this question through more detailed examination of the chemical characteristics of both the phenocrysts and the groundmass. The Iceland plagioclaise phenocryst

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transmission spectra (An89) is compared with emission spectra of oligoclaise (An34), labradorite (An62), bytownite (An85), and anorthite (An95) samples in Figure 2. A close correspondence was found between Ca:Na ratio (as determined by microprobe) and the location of 8-12 μm silicate band of the Iceland phenocryst. No such relationship was observed between composition and groundmass band position. However, comparison with the groundmass spectrum of a hawaiian olivine basalt does reveal slight shifts of the broad 8-12 μm band, suggesting it may be possible to distinguish one groundmass composition from another. A microprobe spatial/compositional mapping analysis is currently being underway to further study the compositional variations in the groundmasses.

**Conclusions.** It has been previously shown [4] that infrared spectroscopy is a powerful tool in distinguishing between rock-forming materials of different anion groups, and between silicates with different silica content. Our work suggests some limitations on extending this capability to distinguishing basalts of differing compositions. The macroscopic crystals (phenocrysts) contribute little to the overall spectrum, which is dominated by the groundmass/glass spectrum which displays band-broadening. Only through detailed study of this component of the IR spectrum will additional compositional information be derived.

A promising result of this study is the effectiveness of IR spectroscopy in revealing chemical information about single crystals. We were able to determine, for example, the Ca:Na ratio in a feldspar to better than 5%. For these microscopic observations, minimal sample preparation was required: fragments were chipped from the hand sample and selected particles ≤ 50 μm were examined under the microscope. Application of this technique in a statistical study of a fragmented rock could tell, for example, the major elemental composition of the crystalline materials, their mineralogical form, and, by combining with the results of similar measurements on the non-crystalline materials, the petrological relationships between these materials. Preparation and analysis of such samples is clearly within the capability of planetary rover sample preparation devices, suggesting IR microspectroscopy could be a useful analytical tool on such vehicles.

**References.** [1] Abrams, M., et al, *J. Geophys Res. B,* in press. [2] Kahle, A., et al, (1988) *J. Geophys Res.,* 93, B12, 15,239-15,251. [3] Malin, M.C. and Anderson, D.L., (1991) in preparation. [4] Christensen, and Luth S. (1987) *Lunar Planet. Sci. XVIII,* 169-170.
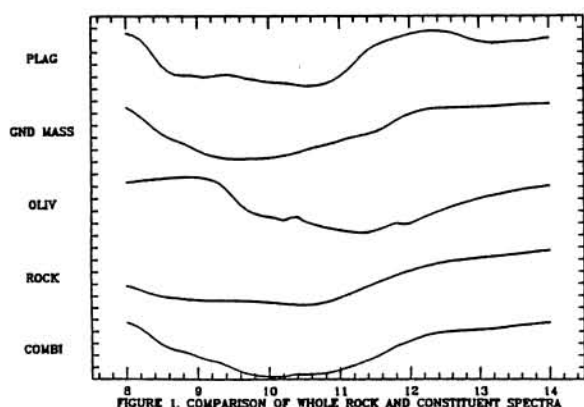


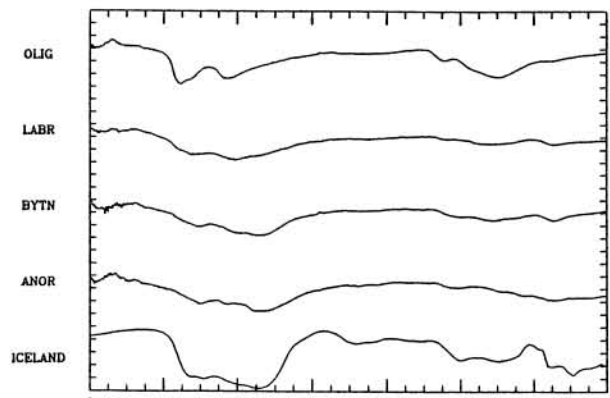FIGURE 1. COMPARISON OF WHOLE ROCK AND CONSTITUENT SPECTRA

FIGURE 2. COMPARISON OF ICELAND PHENOCRYST TO PLAGIOCLAISE FELDSPARS