

DETERMINATION OF MARTIAN SURFACE COMPOSITION BY THERMAL INFRARED SPECTRAL OBSERVATIONS; P.R. Christensen, Dept. of Geology, Arizona State Univ., Tempe, AZ 85287, H.H. Kieffer, U.S. Geological Survey, Flagstaff, AZ 86001, and S. Chase, Santa Barbara Research Center, Goleta, CA 93117.

Visible and infrared spectroscopy are widely used in remote sensing of geologic materials, based on the principle that atoms within a solid produce absorption bands whose wavelengths and strengths are characteristic of the composition and structure of the material observed. Recently, visible and near-infrared (VNIR) spectra have been studied to discriminate geologic materials, in particular Fe, CO₃, H₂O, and OH bearing clays and other weathering products on Earth and on Mars (1,2,3,4,5). However, many geologically important elements, including Si, Al, O, and Ca, do not produce absorption bands in the visible or near-infrared. Therefore, the presence of these elements must be inferred indirectly from VNIR spectra (6).

In contrast, nearly all silicates, carbonates, sulphates, oxides, and hydroxides have thermal-IR spectral features associated with the fundamental vibrational motions of the Si-O, CO₃, Fe, S, and OH ions (7,8,9). The vibrational energy, and therefore the wavelength, of these bands is diagnostic of both the composition and of the crystal lattice structure. Thus, thermal-IR spectra provide a direct means of identifying the composition of many common materials, and for interpreting the structure (i.e. mineralogy) of these materials.

The occurrence and spatial variability of strong absorption bands within the thermal-IR was observed by the Viking Infrared Thermal Mapper (IRTM) experiment. With spatial resolution typically 10 km, variations of spectral emissivity, attributed to the surface, on the order of 0.1 were observed. The IRTM, however, was a broadband radiometer (bandwidth 200 to 400 cm⁻¹) with bands centered at 1400, 1200, 900, and 500 cm⁻¹ while the widths of individual thermal-IR spectral features found in most minerals range from 20 to 200 cm⁻¹. Thus the IRTM data lack the spectral resolution necessary to distinguish between a number of reasonable geologic materials. For example, the emissivity variations observed by the IRTM could be produced by silicate rocks varying in composition from peridotite (ultramafic) to diorite (acidic), by hematite (iron oxide) or by kaolinite (hydroxide).

High spectral resolution (2.5 cm⁻¹) thermal-IR observations of Mars were made by the Mariner 9 Infrared Interferometer Spectrometer (IRIS)(10). The IRIS spatial resolution, however, was 125 km at best, thus integrating large regions of differing composition. In addition, the IRIS investigation was designed primarily for atmospheric study and most of the observations were made during an extensive dust storm. Thus, few spectral features were initially attributed to surface materials. Recently, we performed a search of all of the more than 21,000 IRIS spectra, using constraints of low atmospheric dust content, low emission angle, and high surface temperature, to maximize surface feature detection. This search produced 23 spectra suitable for surface studies. These spectra do show clear differences that vary systematically with surface albedo and thermal inertia. These observations, together with the more extensive spatial coverage provided by the IRTM, demonstrate that significant thermal-IR spectral features occur in the surface materials of Mars and that the surface composition varies from place to place.

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We conclude, therefore, that a thermal-IR spectrometer with adequate spectral and spatial resolution could determine and map the composition of the surface materials.

We are currently studying the design criteria for a thermal-IR spectrometer for use on future spacecraft. The tradeoffs between mission and instrument constraints and science requirements suggest that the optimal surface resolution would be between 2 and 5 km. Absorption features observed in laboratory measurements can be as narrow as 20 cm^{-1} . Neither the IRTM nor the IRIS data provide observational constraints on the useful spectral resolution because neither was optimized in both the spatial and spectral domain. At present a spectral resolution of 10 to 20 cm^{-1} is being considered. Finally, improvements in uncooled detector technology would allow a factor of 20 improvement in signal-to-noise ratio over that attained by the IRIS instrument, allowing spectra to be obtained with an uncertainty in emissivity of less than 0.002. This resolution would allow excellent spectral discrimination in the relatively strong band observed at high spatial resolution.

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