FIRST AIRBORNE THERMAL INFRARED HYPERSPECTRAL IMAGING OF A DRY LAKE: REAL-WORLD DATA AND TES/THEMIS MARS INTERPRETATIONS.

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Summary: Researchers seek to identify dry lake bed deposits on Mars, if present. The Global Surveyor TES and Mars Odyssey THEMIS are primary tools in this search. However, there are no published thermal infrared spectrometer (hyperspectral) airborne studies of a dry lake bed.

Here we present the first such study and the impacts on TES/THEMIS interpretations. This research addresses a looming gap in the field spectroscopy experience required for complete and rigorous interpretations of TES/THEMIS data. A companion abstract focuses on the relevant Bristol Lake geology [1]. A hallmark of this work is the alliance of field geologists and field spectroscopists.

Background: Past thermal infrared terrestrial analog remote sensing studies used multi-channel radiometer data (e.g., TIMS, MASTER), because airborne hyperspectral (spectrometer) thermal emission data sets were not available.

Kirkland et al. published the first geologic study that used an airborne thermal infrared hyperspectral imager [2]. The study uncovered key spectral effects that occur in the field and that alter TES interpretations, with a focus variations on carbonate textures. Here we extend this first-ever style of fundamental study to cover a dry lake bed (playa).

Site: Bristol Lake is in the Mojave desert, near Amboy. Fig. 1 shows the site studied. Geologic units along the SEBASS line from [3] are:

Qpsh: Silt, clay, and halite salt (Holocene).
Qpsg: Silt, clay, gypsum, and celestite (Holocene)
Qps: Silt and clay (Holocene).
Qya: Alluvium. Sand and poorly sorted sandy gravel.

Instruments: TES hyperspectral (spectrometer) data cover ~6.5–50 µm in 143 channels. In contrast, the supporting terrestrial airborne studies used multi-channel radiometer (multi-spectral) data, mainly the Thermal Infrared Multispectral Scanner (TIMS, 6 bands), or MASTER (10 bands). THEMIS is also a multi-channel radiometer (multi-spectral, 9 bands).

We analyzed unique hyperspectral (spectrometer) images recorded by the Spatially Enhanced Broadband Array Spectrograph System (SEBASS, 7.6–13.5 µm, 1321-740 cm^{-1}, 128 channels) [2, 4]. Terrestrial atmospheric water vapor and CO_2 absorptions limit this terrestrial atmospheric window to ~8–13 µm. SEBASS covers this full range.

Multi-channel radiometer studies leave some aspects of field studies incomplete, because they lack the spectral resolution required to research detailed spectral behavior. Our studies address this gap by moving fundamental research from the laboratory to the airborne/satellite remote sensing perspective.

SEBASS measures with the highest combined spectral resolution and sensitivity (signal-to-noise ratio) of any airborne thermal infrared hyperspectral imager. Fig. 2 shows the signal-to-noise ratio. Additional SEBASS information is in [2, 4].

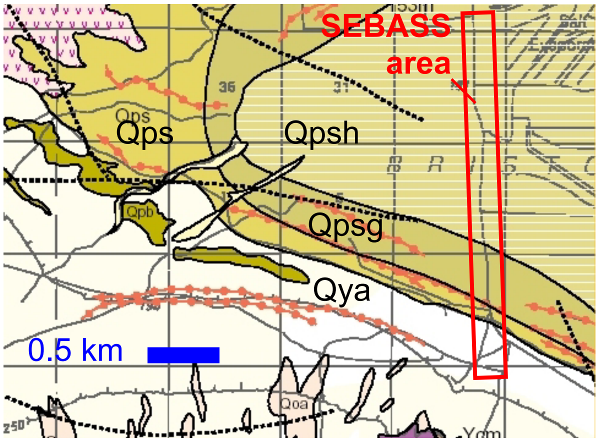

Fig. 1: Site location [3]. The red box illustrates the approximate location of the SEBASS flights. A more regional view is in [1]. Two SEBASS scenes were measured running ~N-S, parallel to Amboy Road.

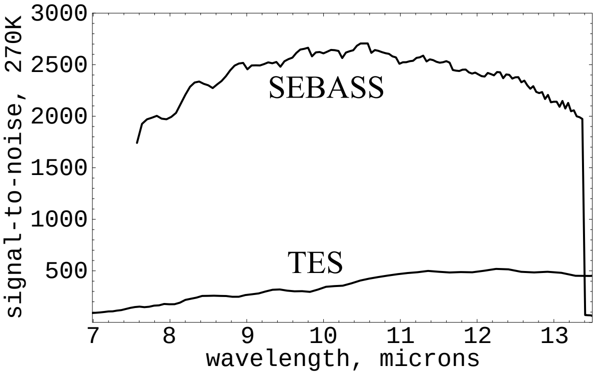

Figure 2: SEBASS and TES sensitivity. This shows the r.m.s. signal-to-noise ratio for a blackbody at 270K [4]. Higher numbers indicate higher sensitivity.

We measured two Bristol Lake SEBASS images on October 11th, 2002, with ~2 m × 2 m spatial resolution per pixel. Each image is 128 pixels by 2000 pixels. Fig. 3 shows a three-band subset of one image (red, green, blue are 8.3, 8.7, 9.2 µm, channels 13, 20, 28).

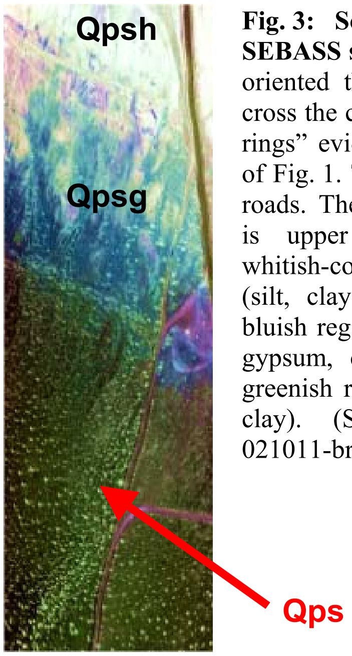

Fig. 3: Southern segment of SEBASS scene. North is up. We oriented the SEBASS flight to cross the compositional "bathtub rings" evident in the lower part of Fig. 1. The linear features are roads. The paved Amboy Road is upper right. The upper, whitish-colored unit is Qpsh (silt, clay, halite). The center, bluish region is Qpsg (silt, clay, gypsum, celestite). The lower, greenish region is Qps (silt and clay). (SEBASS shot 054-021011-brsw).

Preliminary data: Fig. 4 shows example SEBASS spectra from each unit in Fig. 3. The spectra are compensated for the atmospheric transmission and upwelling radiance, using the methods in [2].

The Qpsh (silt, clay, halite) unit shows a very weak ~9.5 µm feature consistent with a silicate (Fig. 4). The signature strength varies with location, but is consistently either weak or absent. The data show no direct evidence of the halite, either in the spectral shape or the brightness temperature. On-site scouting showed the obvious presence of large, well-exposed halite deposits (pictures are in [1]). Massive halite has no diagnostic features in this spectral range, but it can enhance the spectral features of contaminants, which may cause the 9 µm feature.

The SEBASS Qpsg unit spectra are consistent with the presence of sulfate and silicates. The Fig. 4 Qpsg spectrum was recorded of a region covered with indurated sulfate (gypsum and/or anhydrite, pictures are in [1]), which exhibited the strongest sulfate signature.

The Qps spectra are consistent with the presence of silicates (Fig. 4).

Discussion: Laboratory spectra used for TES interpretations show much greater spectral contrast than the field data, consistent with the findings in [2]. Fig. 5 compares the strongest SEBASS sulfate band with laboratory data used for TES interpretations [5]. A resulting interpretation would conclude that very little sulfate is present in a region covered by indurated sulfate. Likely causes of lower spectral contrast are surface roughness and coverage by dust. The true cause requires laboratory characterization.

Implications for TES/THEMIS interpretations are that lake deposits are almost certainly much harder to detect than what is predicted using laboratory spectra of pure, smooth-surfaced samples (e.g., Fig. 5). As a result, interpretations based on non-detection have high uncertainties and should be approached with due caution.

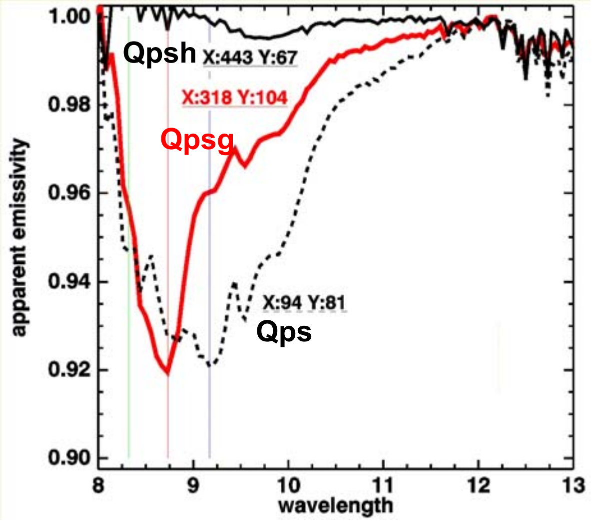

Fig. 4: Sample SEBASS data. The spectra are from the Qpsh unit (upper, solid trace); a strong sulfate signature from Qpsg (middle, red trace), and Qps (dashed). Sharp features are residual atmospheric bands. The labels are the index (location) values.

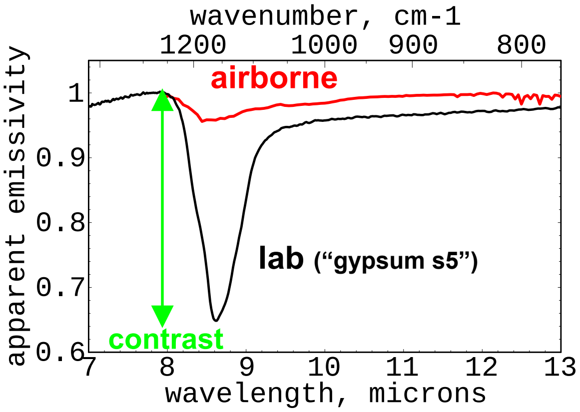

Fig. 5: Comparison of TES interpretation data [5] and real-world data. The green arrow indicates the laboratory spectral contrast (band depth).

References: [1] Burt D. et al. (2003), submitted *LPSC XXXIV*. [2] Kirkland L. E. et al. (2002), First Use of an Airborne Thermal Infrared Hyperspectral Scanner for Compositional Mapping, *Remote Sens. Environ. 80*, 447, www.lpi.usra.edu/science/kirkland. [3] Howard K. A. (2002), Geol. Map-Sheep Hole Mtns, USGS MF-2344. [4] Kirkland L. E. et al. (2001), *Applied Optics 40*, 4852. [5] Christensen P. R. et al. (2000) *JGR 105*, 9735.

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