Challanges in compositional mapping of playas, Yotvata Playa , Israel

Alan Gillespie[1], Rivka Amit[2], Amit Mushkin[1], Onn Crouvi[2,3], Yehouda Enzel[3], Iryna Danilina[1], and Elsa Abbott[4]

1) University of Washington, 2) Geological Survey of Israel, 3) The Hebrew University, 4) Jet Propulsion Laboratory

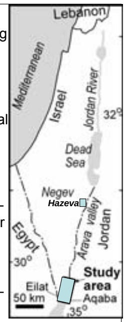
Summary Yotvata Playa is astride the Israel-Jordan border in the Arava valley, in the hyperarid area between the Dead Sea and the Gulf of Aqaba, and is interesting because of its shallow groundwater and gypsic soils. Because of the international border, existing maps have been made by different institutions and have not been coordinated. Remote sensing is of use to integrate the mapping, and Yotvata also acts as a test case for mapping hyperarid soils elsewhere. Multispectral remote sensing was invented to do lithologic mapping, but the problems of identifying mineral constituents of fine-grained soils are significant. Can remote sensing be used in compositional mapping of playas?


Yotvata Playa, looking east to Jordan

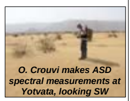
The chief problem from a trafficability standpoint that makes playas such as Yotvata important is that when wet the soils become impassible; when dry they are prominent sources of air-borne dust. Pumping for irrigation has drawn down groundwater significantly, and augering has been used in Jordan to map its depth. We collected soil samples for spectral analysis and attempted to make remote maps that reflected surface roughness, vegetation, and hydration of exposed minerals (e.g., clays). The results were validated by field examination and comparison to previous mapping.

Pedogenic gypsum is hard to detect spectrally, even in collected specimens. Because gypsic crusts are readily identified remotely, this is probably because of the fine-grained nature of the mineral grains, but also because of significant impurities. From the air, the problems are compounded because the gypsum is mostly in the sub-surface and exposed only here and there, in small patches. Pedogenic calcite is similarly difficult to map remotely, as shown by a hyperspectral TIR SEBASS study of Mormon Mesa, Nevada (Kirkland et al., 2002). Studies of sulfate salts in Death Valley have shown that in areas of evaporite concentrations, however, it is possible to recognize different salts (e.g., thenardite, gypsum, calcite) remotely.

Spectral remote sensing is more successful at mapping aeolian deposits, especially sands for which unusual mineral concentrations result from winnowing. Surface moisture and hydrated minerals are easier to detect, and bear a relationship to the patterns mapped in the field. Roughness mapping lived up to its billing as a robust remote mapping technique. Vegetation was mapped correctly. This project investigated the plusses and minuses of remote mapping of playas from the standpoint of parameters important to trafficability: surface mineral composition, vegetation, soil moisture and hydrous minerals, and roughness. Remote detection of sulfate soils will be difficult to realize, but the other techniques are promising.

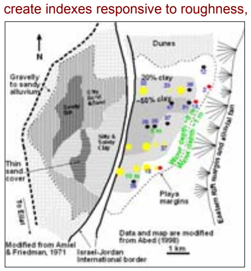


Location of Yotvata


O. Crouvi makes ASD spectral measurements at Yotvata, looking SW

STATEMENT OF THE PROBLEM: Multispectral remote sensing is useful for geologic mapping and identification of rock and mineral units in bedrock and coarse clastics, but it has not been extended very successfully to mapping soils. Can it be used to map soils and particulate deposits in Yotvata Playa and other playas?

APPROACH: We collected grain size vs. depth data in soil pits and assessed mineralogical composition by inspection and SEM, on the surface and in the soil pits. We collected pertinent mineral spectra (0.4-12 μm) from data libraries (http://speclib@jpl.nasa.gov) and measured surface spectra at Yotvata and nearby Sharharot Playa and Hazeva. We collected ASTER and other satellite images and processed them to create indexes responsive to roughness, vegetation, and hydration in clays and clay precursors (Al-OH) and tested these images for detectability of SO4=.



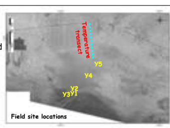
Geological map from Israeli and Jordanian sources showing Yotvata Playa

Surface sample w/gypsum ( ), w/halite ( ) or % clay 37

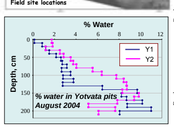
Yotvata Playa: Yotvata is a terminal playa in a tectonic basin that is fault-bounded on its eastern side. In the near surface drainage is blocked by alluvial fans. It may have groundwater connectivity to adjacent basins and is fed mainly from the east by floods recharging alluvial fans. Rainfall is scarce (28±20 mm/yr) and soils are developing in a hyperarid environment. Occasional floods reach the playa but groundwater recharge is the major source of water in the playa. In ~1962 the water table was 2-5 m deep in the west (Gilad,1968) and 0-2 m in the east (Abed, 1998).

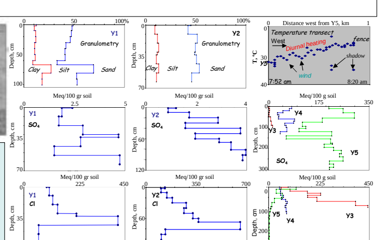
Evaporation of groundwater in the playa center (0.4 mm/day from z=1.8 m: Gilad, 1968) has increased near-surface salinity there to ~150,000 mg Cl/l. Where the sparse vegetation is thickest evaporation is 0.91 mm/day (z=2.2 m). Soils are gypsic/salic and are developed on silty/sandy clay. The playa surface is locally covered by thin sand sheets and dunes.

RESULTS: Field data on water, salts, grain size, and temperature variability are shown below and to the right.

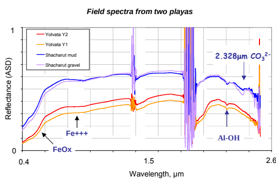


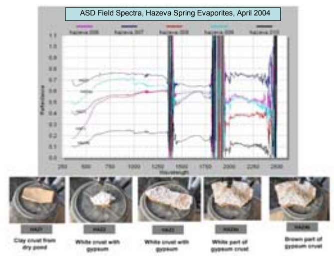

Measuring soil water, Yotvata



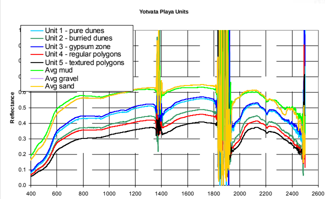


RESULTS (cont) – Field spectra show that some mineral species can be identified, but not all important ones. SO_4, for example, is hard to see in the spectra although it is present in large amounts. CO_3 likewise appears to be hard to identify. Spectra of significant field units show that they, unlike bedrock units, cannot be distinguished on the basis of composition alone.

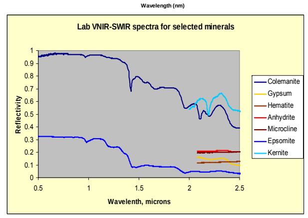


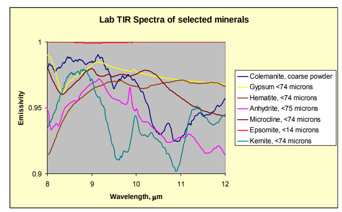


VNIR-SWIR spectra of playa surfaces show mainly clays, carbonate, and Fe oxides

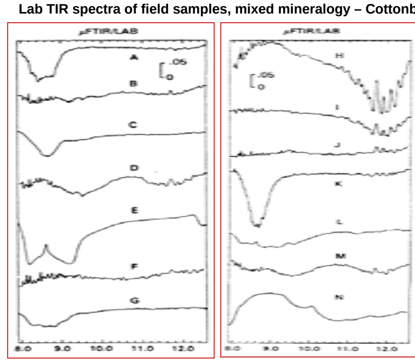


Lab spectra (below) show that playa minerals are straightforward to distinguish or identify. Fe oxides & Fe-bearing minerals are best studied in the visible and near infrared (0.4 – 1.4 μm). The shortwave infrared (1.4-2.5 μm) is well-suited for hydrous minerals, sulfates, and carbonates. Silicates, borates, and sulfates show up well in the thermal infrared (8-12 μm). The reasons are well known and have been elaborated for decades





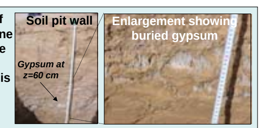
Lab TIR spectra of field samples, mixed mineralogy – Cottonball Playa, Death Valley, California

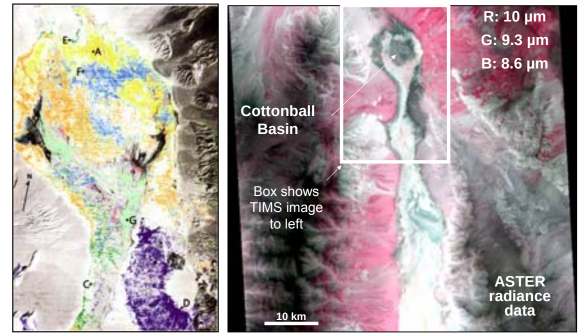


- **A** - thenardite-rich crusts in saline facies of sulfate zone
- **B** - silty halite, smooth facies, and carbonate zone, silty facies
- **C** - gypsum crusts
- **D** - illite/muscovite-rich alluvial deposits
- **E** - quartz-rich fan gravels and mudflats
- **F** - massive halite and silty halite, rough facies
- **G** - mixed silicate and evaporite mineral crusts on floodplains
- **H, I, J** - smooth halite-rich crusts on floodplains
- **K** - gypsum crusts
- **L** - quartz-rich alluvial deposits
- **M** - illite/muscovite-rich alluvial deposits
- **N** - mixed silicate and evaporite mineral crusts on floodplains

These spectra show that, at the cm scale, natural playa surfaces are readily separable and even have information diagnostic for composition. Yet at Yotvata, spectral distinction among units was negligible, even at the 10-cm field spectrum scale. Why??

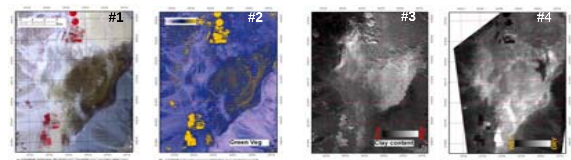
Gypsum comprises a large fraction of the soil at z=60 cm (coarsely crystalline lenses 2-5 cm thick) but little is visible on the surface. Gypsum affects the mechanical properties of the soil but is essentially invisible from satellite. Gypsum exposed at the surface is commonly very fine-grained.



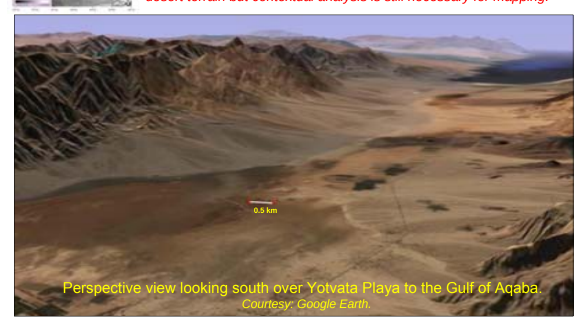


*Images of other playas show that compositional mapping is feasible there. Airborne six-channel thermal IR scanner images (TIMS) of Cottonball Basin in Death Valley, California, show mineral zoning in saline playas (Crowley & Hook, 1996). The image has been classified and the units matched with geological units mapped on the ground. Thenardite-rich crusts in saline facies of sulfate zone appear **yellow**; silty halite, smooth facies, and carbonate zone, silty facies are **orange**; gypsum crusts are **red**; illite/muscovite-rich alluvial deposits are **dark blue**; quartz-rich fan gravels and mudflats are **green**; massive halite and silty halite, rough facies are **cyan**; mixed silicate and evaporite mineral crusts on floodplains are **light green**. The ASTER image on the right is simply a TIR false-color composite, but many lithologic units may be identified in the mountains and in the alluvial fans (Gillespie et al., 1984). **The ASTER image shows that compositional mapping in bedrock and clastic fans can be straightforward: In this case, quartzites and felsic rocks are red. Significantly, the playa units could be distinguished but not identified, yet field spectra suggest they should be identified also.***

What prevents better remote mapping in soils? 1) Minerals loose spectral contrast when they are finely particulate (e.g., Conel, 1969; Kirkland et al., 2002). 2) Soils are mineral mixtures, diluting spectral features. 3) Many key mineral concentrations are buried and hidden from view. It is significant that coarse-grained evaporite concentrations can be mapped readily.



Spectral remote sensing is effective at quantitatively mapping key terrain parameters in playas. Image #1 above is a false-color ASTER view of Yotvata. #2 shows vegetation cover mapped from the chlorophyll absorption band. #3 shows SWIR absorption associated with Clays. #4 shows soil moisture. #5 (to left) shows surface roughness at the <15m scale calculated from stereo ASTER images (Mushkin & Gillespie, 2005). *State-of-the-art remote sensing can help map desert terrain but contextual analysis is still necessary for mapping.*



Perspective view looking south over Yotvata Playa to the Gulf of Aqaba.
Courtesy: Google Earth.

Sponsors
-This research was sponsored by the Army Research Office and by the NASA Terra/ASTER Program