MAKHTESH RAMON, A SUPER SITE FOR CALIBRATION AND VALIDATION OF IS SENSORS

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KEYWORDS

HSR Background, Lithology, HSR Sensors, Spectral signature, Field campaign, Remote sensing

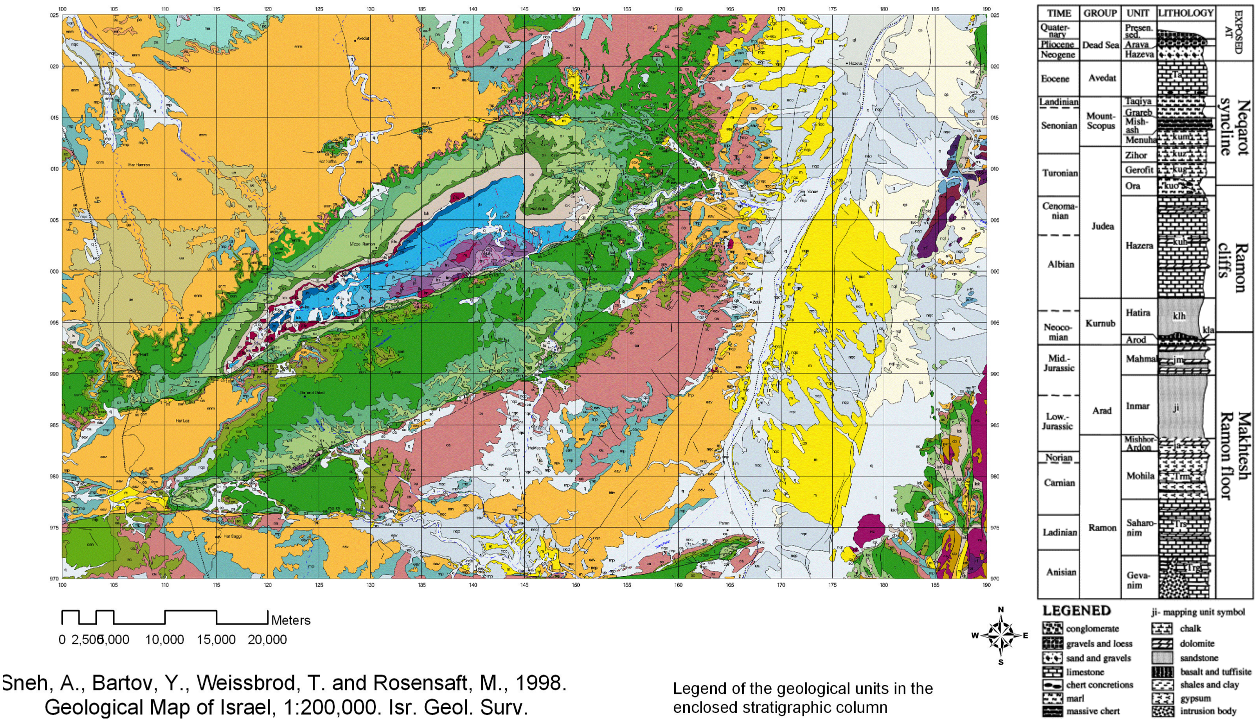
ABSTRACT

Makhtesh Ramon is one of the most promising sites for HSR sensor calibration worldwide; it is located in southern Israeli Negev Desert. The region is generally a flat drainage basin bounded by steep walls. Due to the arid conditions, vegetation and soil cover are limited; in addition, the area is nearly free of clouds throughout the year. Makhtesh Ramon expose lithologies from the Middle Triassic to Resent. The region was declared a National Reserve Geological Park and as such it is preserved in its natural state. Two scientific centers equipped with state-of the art meteorological stations and satellite receiving stations are located in the vicinity. Long lasting legacy of scientific research offers precise dataset of geoscience based parameters. In addition also a large archive of HSR data is available from variety of sensors in several spatial resolutions starting with field measurements (ASD) through airborne (AISA-ES, GER 63, CASI and DAIS-7519), space borne (CHRISS-PROBA, ASTER and Hyperion). The present state of research includes increasing the spectral mapping resolution by ASD field campaigns and extensive laboratory analyses. Further stages will include production of spectral calibration datasets designated for any specific sensor.

INTRODUCTION

Reliable interpreting of Hyperspectral Remote Sensing data must be based on high quality calibration of the on-board sensors system. Several methods, which differ in approaches and evaluation standards, can be used for this purpose. The Preflight Calibration process allows high accuracy calibration of parameters such as sensitivity to polarization, stray-light effect, linearity, and the Modulation Transfer Function. One type of in-flight calibration is done by mono band luminance artificial (lamps) or natural (Sun) light sources, through filters to the optical system of the sensor. Since calibration should simulate the natural luminance of the object the calibration by on-board light sources fail in that point since they do not have an appropriate spectral distribution (Healey and Slater, 1999). The use of solar diffuse panel can supply better calibration, although it might suffer of degradation due to environmental effects. In order to increase the reliability of on-board calibration and to determine the top of atmosphere (TOA) radiance, an unambiguous matching of spectral reflectance of known polygons at ground level their on-board reference dataset should be done.

This procedure require long term verification and validation since optical properties can be affected by moisture, presence of rock pieces of different size, vegetation, and other parameters, which might cause non-Lamberian reflectance and BRDF effect. An optimal area should be free of clouds and characterized by lithological inhomogeneity, hence, each calibration polygon should consist of different rocks and rock forming minerals. In addition the regressive matching of minerals spectra to each identified lithological unit at sensor images (after correction of atmospheric effects) can be a reliable indicator of sensor calibration efficiency (Karnieli et al., 2008). Ben Dor et al., 1999 and Clark, 1999 demonstrated spectral definition lithological surfaces by measurements of field spectra in the 400 to 2500 μm band (VNIR-SWIR) and also discrimination of spectrally uniform areas. Other studies indicated that mapping of such surfaces is possible and also costs and time efficient (Taylor, 2000; Kozak and Duke 2004 and Lawrence et al, 2005). Crouvi et al (2006) found that the spectral properties of arid areas depend on the degree of formation of desert pavement. Spectral mineralogical mapping of Makhtesh Ramon was first assessed by Kaufmann et al. 1991 with hyperspectral. Ben Dor and Kruze 1995 emphasized the importance of this area as an international global calibration site for IS sensors (airborne or orbital).



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Legend of the geological units in the enclosed stratigraphic column

Figure 1: Location and Geological maps of Machtesh Ramon

The Makhtesh Ramon is a deeply eroded anticline that exposes a high variety of Mesozoic and Cenozoic formations. The region is considered arid to extremely arid and it is nearly cloud free; with mean annual rainfall of about 85 mm at the northern rim and about 56 mm at the central part. Mean daily temperature in July is 34 ^{o}C, which drops to 12_5 ^{o}C in January, whereas the mean annual temperature is 17±19 ^{o}C. The lithological exposure reviles variety of minerals with an available detailed spectral library. The radiometric background consists of dark and bright flat targets (sand dunes and basalt). The area has sparse vegetation coverage and is characterized by two flat terrains at distinct elevations with a vertical distance of about 500 m between them. The Ramon erosional `cirque' is 40 km long and 12 km wide, its altitudes range from 1020 m on the western rim to 420 m a.s.l. near the outlet of the main wadi (Nahal Ramon). This ephemeral stream is 39 km long within the crater (Figure 1), and drains most of it. Nahal Neqarot, which flows east of the Ramon anticline towards the Dead Sea, serves as the local erosional base level of the Ramon valley (Plakht et al., 2000).

The Triassic rocks are about 500 m thick and are composed of carbonate, gypsum, shale, sandstone and quartzite lithofacies (Zak, 1963). The Jurassic section is about 400 m thick (Nevo, 1963) and is composed mainly of friable sandstones of Inmar Formation with a subordinated representation of carbonate rocks, siltstones and clays (Goldberg, 1970). The Early Cretaceous Hatira Formation is divided into three members: the lower and upper members are composed of loose sandstones 5±40 m and 80±120 m thick, respectively. Sandstone members are separated by a basanite unit 100 m thick in the western part of Ramon Crater (Eyal et al., 1996), and 0±30 m in its central part. The cliffs surrounding the crater are built of 300 m thick hard limestones and dolomites of the Middle Cretaceous Hazera Formation. The Quaternary development of Ramon Crater can be generalized as the alternation of periods of erosion and stability, caused by periodic lowering of base level. The first stage of base-level lowering began with erosional activity, associated with the deformation along the Dead Sea-Arava Rift Valley. An interrupted incision of the Ramon drainage system developed since the Pliocene (Ben-David and Mazor, 1988). The Quaternary landscapes of the Ramon Crater area had formed by different alluvial dispositions, as well as by pediment cover. They occupy 29% and 23% respectively of the total area (241,5sq. km). Different types of slopes, aeolian forms and alluvial fans occupy 17% of the total area (Placht, 1996).

METHODOLOGY

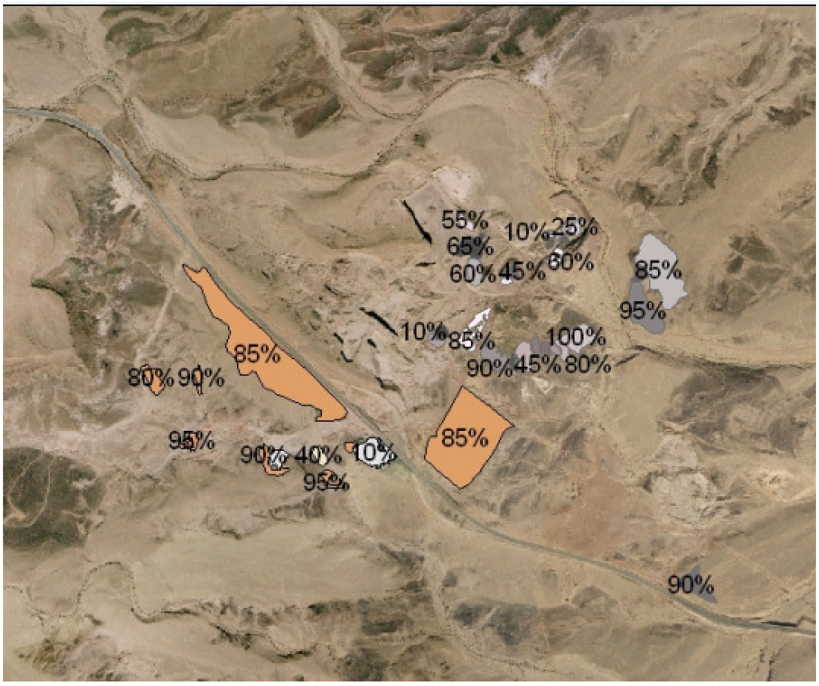
The preparation of IS calibration site include several stages. Investigation of the proposed site is first done by visual interpretation of the different maps followed by field survey. Parameters such as the degree of desert pavement development and gravel coverage are being done during this stage. In addition, also target polygons determination of different lithological exposure. The various surfaces were measured with ASD Field Spec. Pro. both in-situ with bare fiber-optic and at the laboratory with a contact prob. In addition for each polygon morphologic definition included percentage of stones and vegetation and color according to the Munsell scale. For each poligon GPS positioning was carried and digital pictures were also taken. All ground sites were sampled during 2006-2008. It is generally accepted that an area measuring 4×4 pixels around a selected point represents a favorable ground area for an image pixel to later represent the ground. Data processing and Spectral lithological mapping was done with ENVI software with following spectral library: the IGCP-64 (Kruse and Hauff, 1993), the JPL Spectral-Database (Crove et al, 1992), JHU and USGS for correlation with primarily pure minerals. The spectral library of the ground spectra was resampled into the AISA-ES (Spectral Imaging, LTD) flight configuration to allow comparison between them.

The absorption features were identified directly from each spectrum, and from its continuum removal spectrum. Continuum removal was used to identify the exact locations of the absorption features and to calculate the band depth of absorption features from field and image spectra. In cases where the absorption feature was shallow, we quantified it by measurement of the slope of the reflectance values around the feature. For all plot we measured average spectra by using 10% deviation. Finally, a spectral lithological map was produced by using programm Arc Map.

The airborne hyperspectral data acqusition was done by pushbroom type AISA-ES sensor with flight configuration of 288 bands in the VNIR-SWIR reflective region. The data acquired at 14:00 local time on March 25, 2004; flight direction was to the southwest. Six flight lines were flown to cover center of the area of Machtesh Ramon at an altitude 8208m above see level. Atmospheric correction was performed by ACORN and then was completed from six lines geometrically rectified using ortho-rectified air-photo of the area (UTM coordinates). The correction procedure included also Minimum Noise Fraction (MNF) procedure to noise reduction procedure, signal–to-noice ratio (SNR) evaluation of the reflectance image and cross track calibration illumination. Verification of the field and calibrated image spectra was done by comparison of average field reflectance spectrum from selected sites to the laboratory spectra and to the spectra of pure minerals taken from the JPL spectral library. For the final calibrated image data verification the average verified field reflectance spectrum and image spectra were also compared.

RESULTS AND DISCUSSION

Evaluation of lithologically homogenous polygons and smoothness is based on the degree of desert pavement development (Fig. 2). The well developed areas are characterized by combination of different size (boulders and pebbles) mostly of ironized sandstones and less by limestones, both with spectrally insignificant matrix of fine particles of sand and carbonate dust. Similarity of spectral characteristics of the two types of deposits in each area allowed computing mean values for their spectra. Figure 3 (Right) present absorption properties of divalent iron in the VNIR band, of ironized sandstone (typical shoulder at 2.17 Mm, and a doublet at 2.26-2.35µm) that can also be found also in kaolinite. Figure 3 (left) present typical absorption of calcite for carbonates in the SWIR band. These groups of deposits are forming homogenous calibration areas (with the gravel content of 50-80% and 30-50% respectively), with combination of sandstone and carbonate, in the in the first type of rocks (Fig. 3). Visual analysis reveals a spectra with known absorption properties of iron in VNIR and mixture of kaolinite and montmorillonite in SWIR bands, (properties of clay minerals in 2205 µm). Spectrally homogeneous calibration areas can be identified in structures of different genesis with strongly developed desert pavement. Thus, in the areas identified sedimentary rocks are represented by silicates and carbonates (Fig 5). The silicates include Triassic quartzite and Cretaceous chert, as well as ironized sandstone.



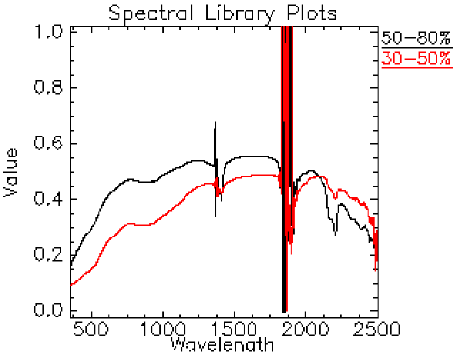


Figure 2: gravel coverage percentage of the Gvanim area (Left) and average spectra of the rocky (50-80% of gravel) and moderately rocky (30-50%) rusty sandstone (above).

Carbonates are represented by the Cretaceous chalk and Triassic limestone with pronounced iron properties in the VNIR and calcite in the SWIR bands (Fig. 3). Metamorphic and volcanic rocks build only spectrally homogenous areas of gabbro and basalt, with characteristic absorption properties of iron an clayey minerals in gabbro (Fig. 4 right). Triassic gypsum deposits are common in the study area and do build homogenous areas within the Mohila formation, revealing characteristic spectral properties in the 1500 µm area (Fig. 4 left).

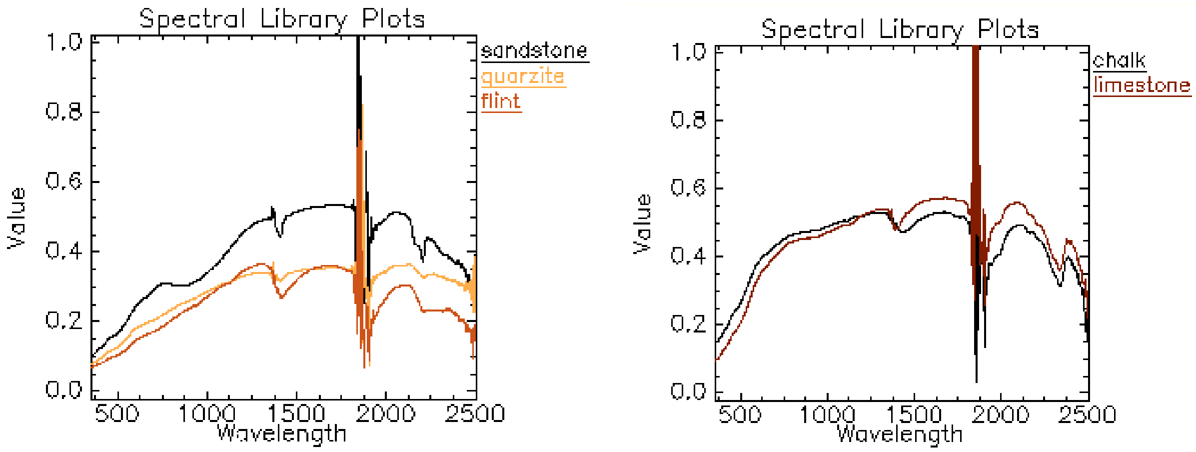


Figure 3: The average spectra of the sedimentary silicates (Right) and of carbonates (Left).

Spectral similarity was the base for construction of spectrally identified field sites, and then for mapping of these areas, i.e. for compilation of their lithological spectral map, yielding a spectral maps of the studies areas.

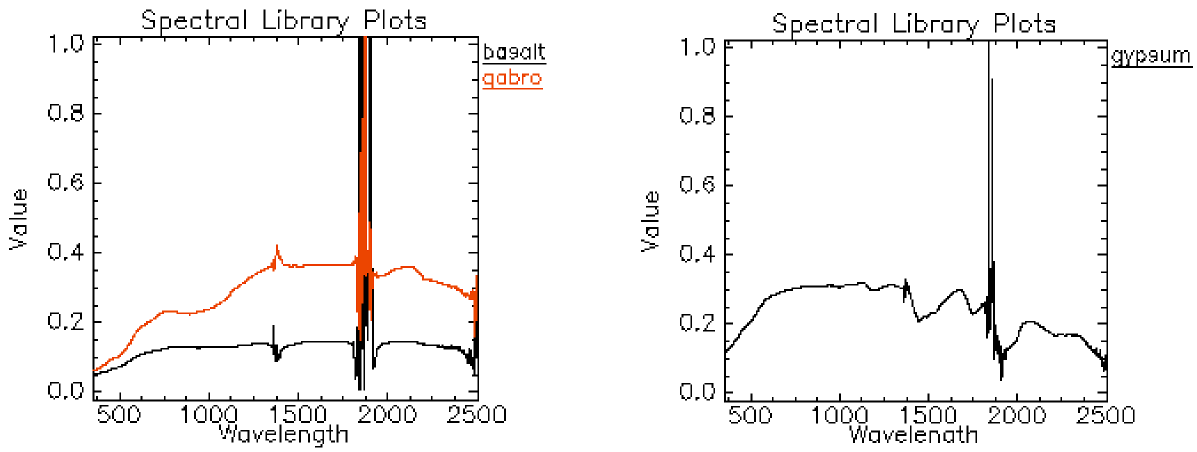


Figure 6: The average spectra of the igneous rocks (Right) and of gypsum (Left)

CONCLUSION

The preliminary study indicate that the geological variability of Machtesh Ramon can supply a reliable spectral identification and mapping of large number of lithologically similar areas, which are commensurable with the pixel size of the on-board sensors. All the identified field spectra of the rock forming minerals correspond to the laboratory and spectral library ones. Comparison of the verified field and image spectra (AISA-ES) has ascertained their high concordance, proving that the regional conditions are optimal. The suggested method, include comparison of known spectra within defined boundaries that represents various cartographic elements of Machtesh Ramon, to an on-board calibration dataset designated for and specific instrument. This procedure may provide precise assessment and calibration of the spectral reaction for each sensor.

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