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DETERMINING THE SPECTRAL CHARACTERISTICS OF ROCKS USING FIELD SPECTROMETRIC DATA AND DISCRIMINATING THEM IN ASTER SATELLITE IMAGERY (A CASE STUDY OF THE VAXSHIVAR SITE)





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Abstract. *This article presents a methodology for using rock spectral curves obtained through field spectrometry to discriminate surfaces spectrally similar to reference samples in ASTER multispectral satellite imagery. The spectral characteristics of rock samples collected under field conditions at the Vaxshivar site were investigated. Spectra acquired using a Spectral Evolution PSM-3500 spectrometer were compiled into a local reference spectral library within the ENVI software environment. The research methodology encompasses satellite image preprocessing, matching field spectra to the sensor's spectral bands, and identifying spectral targets using the Target Detection Wizard module. Differences in the shape and relative amplitude of the spectral curves of gabbro-diabase, altered intrusive rock, and granite samples selected as references were qualitatively characterised. The integrated application of field spectrometry and remote sensing data provides a basis for discriminating lithological targets and selecting prospective sites for further geological investigations. Independent field observations and laboratory analyses are required to assess the geological reliability of the identified spectral targets.*

Keywords: *field spectrometry, Spectral Evolution PSM-3500, spectral curve, spectral library, ASTER, ENVI, Target Detection Wizard, gabbro-diabase, granite, altered intrusive rock.*

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ОПРЕДЕЛЕНИЕ СПЕКТРАЛЬНЫХ ХАРАКТЕРИСТИК ГОРНЫХ ПОРОД ПО ДАННЫМ ПОЛЕВОЙ СПЕКТРОМЕТРИИ И ИХ ВЫДЕЛЕНИЕ НА КОСМИЧЕСКИХ СНИМКАХ ASTER (НА ПРИМЕРЕ УЧАСТКА ВАХШИВАР)

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Аннотация. *В статье рассмотрена методика использования спектральных кривых горных пород, полученных методом полевой спектрометрии, для выделения поверхностей, спектрально сходных с эталонными образцами, на мультиспектральных космических снимках ASTER. Изучены спектральные характеристики образцов горных пород, отобранных в полевых условиях на участке Вахшивар. Спектры, полученные с помощью спектрометра Spectral Evolution PSM-3500, объединены в локальную эталонную спектральную библиотеку в программной среде ENVI. Методика исследования включает предварительную обработку космических снимков, согласование полевых спектров со спектральными каналами сенсора и выявление спектральных объектов с помощью модуля Target Detection Wizard. Качественно охарактеризованы различия формы и относительной амплитуды спектральных кривых образцов габбро-диабаза, изменённой интрузивной породы и гранита, выбранных в качестве эталонов. Совместное использование данных полевой спектрометрии и дистанционного зондирования создаёт основу для выделения литологических объектов и выбора перспективных участков для дальнейших геологических исследований. Для оценки геологической достоверности выделенных спектральных объектов необходимо проведение независимых полевых наблюдений и лабораторных анализов.*

Ключевые слова: *полевая спектрометрия, Spectral Evolution PSM-3500, спектральная кривая, спектральная библиотека, ASTER, ENVI, Target Detection Wizard, габбро-диабаз, гранит, изменённая интрузивная порода.*

DALA SPEKTROMETRIYASI MA’LUMOTLARI ASOSIDA TOG‘ JINSLARINING SPEKTRAL XUSUSIYATLARINI ANIQLASH VA ULARNI ASTER KOSMIK TASVIRLARIDA AJRATISH (VAXSHIVAR UCHASTKASI MISOLIDA)

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Annotatsiya. *Maqolada dala spektrometriyasi yordamida olingan tog‘ jinslarining spektral egri chiziqlari asosida ASTER multispektral kosmik tasvirlarida etalon namunalarga spektral jihatdan o‘xshash yuzalarni ajratish metodikasi yoritilgan. Vaxshivar uchastkasida dala sharoitida olingan tog‘ jinsi namunalarining spektral xususiyatlari o‘rganilgan. Spectral Evolution PSM-3500 spektrometri yordamida olingan spektrlar ENVI dasturiy muhitida mahalliy etalon spektral kutubxonaga birlashtirilgan. Tadqiqot metodikasi kosmik tasvirlarni dastlabki qayta ishlash, dala spektrlarini sensorning spektral kanallariga moslashtirish hamda Target Detection Wizard moduli yordamida spektral obyektlarni aniqlash bosqichlarini qamrab oladi. Etalon sifatida tanlangan gabbro-diabaz, o‘zgargan intruziv jins va granit namunalarining spektral egri chiziqlari shakli hamda nisbiy amplitudasidagi farqlar sifat jihatidan tavsiflangan. Dala spektrometriyasi va masofaviy zondlash ma’lumotlaridan birgalikda foydalanish litologik obyektlarni ajratish hamda keyingi geologik tadqiqotlar uchun istiqbolli uchastkalarni tanlashga asos yaratadi. Ajratilgan spektral obyektlarning geologik ishonchliligini baholash uchun mustaqil dala kuzatuvlari va laboratoriya tahlillarini o‘tkazish zarur.*

Kalit so‘zlar: *dala spektrometriyasi, Spectral Evolution PSM-3500, spektral egri chiziq, spektral kutubxona, ASTER, ENVI, Target Detection Wizard, gabbro-diabaz, granit, o‘zgargan intruziv jins.*

Introduction. The spectral curves of rocks and minerals are measured using spectroradiometers, most of which cover a wavelength range from 0.350 to 2.7 μm. To facilitate the broad use of the spectral measurements obtained, they are compiled into electronic spectral

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libraries and integrated into software modules specialized in remote sensing (Goipov & Asadov, 2022).

A spectral library is a database in which spectra are stored together with metadata. Each spectrum contains the same information as a corresponding data block: a set of values, their corresponding wavelengths, and information on the units of measurement (NV5 Geospatial, n.d.-c).

The importance of a local spectral library lies in the ability to work with samples collected from the study area. Each reference spectrum is linked to the sample code and its geological description. The spectral library and target detection tools in ENVI are used to compare field reference spectra with image spectra (Exelis Visual Information Solutions, 2014; NV5 Geospatial, n.d.-c).

The aim of the study is to describe the spectral characteristics of samples collected from the Vaxshivar site and to present a methodology for discriminating similar rock surfaces in ASTER satellite imagery using their reference spectra. The main objectives are to compile reference spectra in ENVI, match the data for spectral comparison, and establish criteria for the geological interpretation of the discriminated targets.

Methods. Goipov and Asadov (2022) describe approaches to creating spectral libraries from field and laboratory measurements and using them in remote sensing software. Goipov, Turapov, et al. (2020) mapped mineral indices in the Kokpatas–Okzhetpes trend using ASTER band ratios. Goipov, Khasanov, et al. (2020) addressed the study of mineralized zones in the Bukantau Mountains using satellite imagery in the short-wave infrared range.

The dissertation abstract by Khasanov (2024) presents spectral anomalies and hydrothermal alteration zones in the Derbez–Kokpatas areas and the results of comparing them with geological data. These studies provide a basis for the geological interpretation of multispectral data. The present study focuses on comparing the field spectra of three samples collected from the Vaxshivar site with ASTER imagery using them as local references.

The methodological framework of the study follows a sequence of acquiring field spectra, creating a local spectral library, preparing satellite imagery, matching reference spectra to sensor bands, and searching for spectral targets in the imagery. Field measurements establish the geological meaning of the reference spectrum, while spectral resampling enables its mathematical comparison with satellite imagery (Goipov & Asadov, 2022; NV5 Geospatial, n.d.-c).

Spectral measurements were acquired using a Spectral Evolution PSM-3500 portable spectrometer. The instrument covers the 350–2500 nm range. According to the manufacturer's technical specifications, its spectral resolution is 3.5 nm within the 350–1000 nm range, 10 nm at 1500 nm, and 7 nm at 2100 nm. The spectral sampling intervals are 1.5, 3.8, and 2.5 nm, respectively; this quantity differs from spectral resolution (Spectral Evolution, n.d.).

The VNIR bands of the ASTER sensor have a spatial resolution of 15 m, while the SWIR bands have a spatial resolution of 30 m. The SWIR region comprises six bands spanning 1.600–2.430 μm. VNIR and SWIR data are suitable for comparison with the spectral reflectance measured by the field spectrometer; the TIR bands at wavelengths above 8 μm fall outside the measurement range of the PSM-3500 (NASA/Jet Propulsion Laboratory, n.d.-a; Spectral Evolution, n.d.).

Acquisition of field spectra. When measuring spectral reflectance, the sample and the white calibration panel are recorded under the same illumination and observation conditions. The instrument's dark signal and the calibrated response of the white reference are taken into account. To reduce the effects associated with moisture, weathering rinds, and surface irregularities, the measurement geometry should be kept as consistent as possible. When creating a spectral library, it is important to retain the original spectral data exported from the spectrometer, the measurement conditions, and the geological description of the sample together (Goipov & Asadov, 2022; Specim, 2026).

Creation of the spectral library. The spectra of the SP-1, SP-2, and SP-3 samples collected from the Vaxshivar site were imported into ENVI and labeled with the corresponding rock names. The Spectral Library Builder tool is used to store the spectra. In ENVI, the library is stored as a .sli (spectral library) file with its associated .hdr (header) file (NV5 Geospatial, n.d.-c).

Preprocessing of ASTER imagery. Before processing, the product level, band composition, wavelengths, and quality layers of the imagery are checked. The need for radiometric calibration and atmospheric correction depends on the product level. FLAASH (Fast Line-of-sight Atmospheric Analysis of Hypercubes) in ENVI or another suitable correction method may be used to convert radiance values to reflectance. Before applying an additional atmospheric correction to imagery provided as Surface Reflectance, its metadata are checked for previously applied corrections. The reference and image values must be expressed on the same reflectance scale (NV5 Geospatial, n.d.-a).

When selecting ASTER SWIR archive data, the acquisition date and detector quality must be checked. According to NASA/JPL, SWIR data acquired from April 2008 onward are unusable; saturation-related defects were also reported during some earlier periods. Therefore, SWIR-based mineralogical analysis should rely only on archive data whose quality has been checked (NASA/Jet Propulsion Laboratory, n.d.-b).

Matching field spectra to ASTER bands. The PSM-3500 records a detailed spectral curve, whereas ASTER records an integrated response over broader band intervals. Therefore, reference spectra are matched to the spectral structure of the imagery using the Spectral Library Resampling tool. Where the sensor's spectral response functions are available, field spectra are matched to the sensor bands using these functions. Otherwise, the central wavelengths of the bands and their full spectral widths at half of the maximum response (FWHM — Full Width at Half Maximum) are used. Each reference spectrum is resampled to obtain values with the same number and order as the bands used in the imagery. Matching is performed only within the wavelength range shared with the imagery (NV5 Geospatial, n.d.-c).

Searching for targets in ENVI. The prepared imagery is loaded into the Target Detection Wizard module, and the spectra of the SP-1, SP-2, and SP-3 samples collected from the Vaxshivar site are selected as target reference spectra (Figure 1). Depending on the characteristics of the algorithm, background spectra may also be extracted from the imagery itself. The module generates rule image layers that represent the match between the reference spectra and the imagery; the discrimination threshold is determined using these layers and verified sites. Where necessary, the discriminated targets are exported as ROIs, a classified raster, or a vector layer (Exelis Visual Information Solutions, 2014).

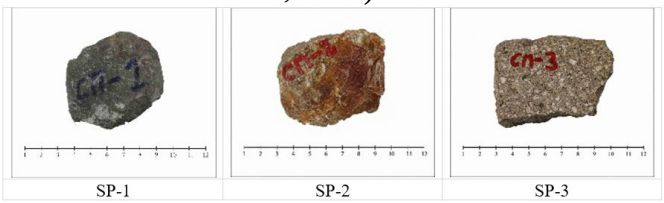


Fig.1. Samples collected from the Vaxshivar site.

To assess spectral similarity, the SAM (Spectral Angle Mapper) method calculates the angle between the pixel and reference spectra: a smaller angle indicates a closer match. MF (Matched Filtering) and MTMF (Mixture Tuned Matched Filtering) are designed to separate the target spectrum from the background response; MTMF additionally generates an infeasibility layer that helps identify falsely detected pixels. The choice of algorithm should be appropriate for the image bands, the characteristics of the target surfaces, and data quality. The discrimination threshold is not adopted as a universal value but is selected for the imagery and control targets (Exelis Visual Information Solutions, 2014; Kruse et al., 1993; NV5 Geospatial, n.d.-b).

Results. The sample curves displayed together in ENVI show differences in shape and relative amplitude between the reference spectra (Figure 2). The spectrum of the SP-1 gabbro-diabase sample has a lower amplitude and a considerably flatter appearance than the other two spectra. The curve of the SP-2 altered intrusive rock exhibits distinct rises and dips. The spectrum of the SP-3 granite sample lies above that of SP-1 over most of the wavelength range.

The SP-2 curve exhibits dips at approximately 1.4, 1.9, and 2.2 μm in the graph. These values are not absorption centers calculated from the unprocessed original spectrum but approximate descriptions of their positions in the graph. Measurement quality and surface condition should be taken into account in their mineralogical interpretation. In particular, the dips around 1.4 and 1.9 μm cannot be regarded as diagnostic features of a single mineral.

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These differences between the reference spectra provide a basis for defining three distinct spectral targets for targeted searching. However, some differences in the detailed spectral curves are averaged when they are matched to ASTER bands. Therefore, the geological meaning of a class in the imagery is assessed in relation to the sample spectrum, the sensor's spectral capabilities, and pixel composition (Goipov & Asadov, 2022; NV5 Geospatial, n.d.-c).

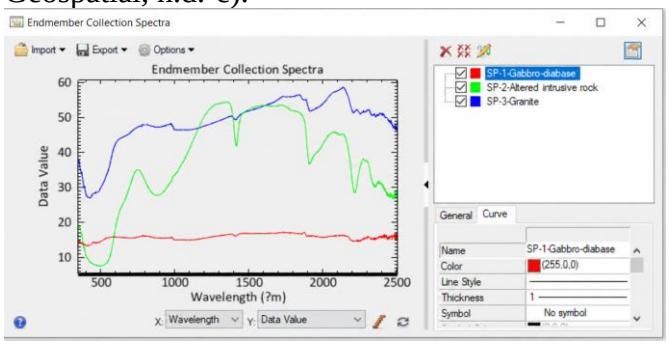


Fig.2. Spectral curves of the samples in ENVI.

The spatial distribution of spectral targets discriminated in ENVI using the reference sample spectra at the Vaxshivar site is shown in Figure 3.

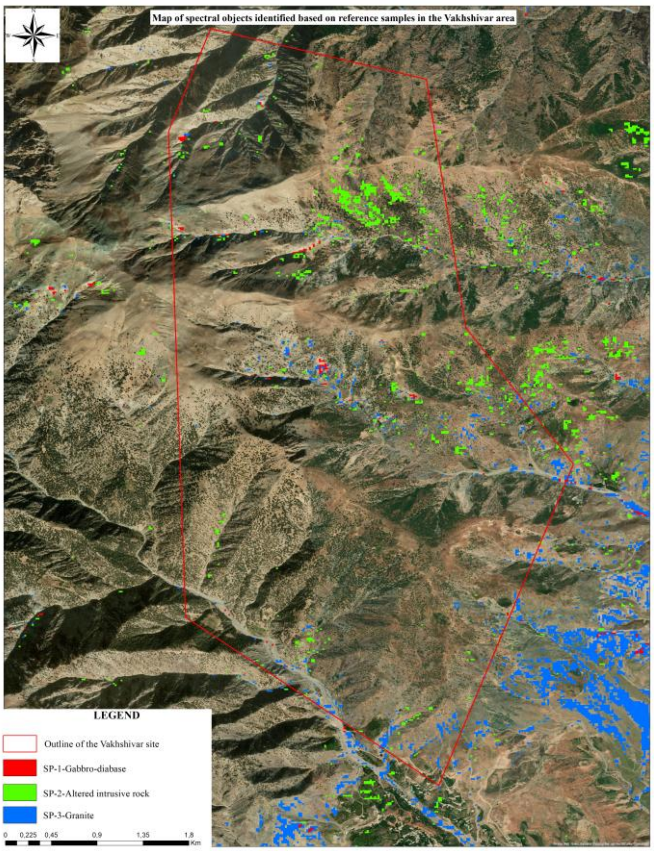


Fig.3. Map of spectral targets discriminated using reference samples at the Vaxshivar site.

Discussion. The main advantage of using field spectra is that the target sought in the imagery is linked to a reference sample collected from the study area itself. At the same time, the spectrum of a single sample does not encompass all compositional and surface variations of a rock type. Working with three reference spectra is suitable for targeted searching for selected objects, but may be insufficient for a complete classification of all lithological types in the area. When expanding the library, it is advisable to include spectra of the same rock collected from different outcrops (Goipov & Asadov, 2022).

An ASTER pixel may contain soil, vegetation, or other materials in addition to rock. The spectrum of such a mixed pixel differs from that of an individual sample. The ability to discriminate a narrow dike or outcrop smaller than the pixel size as a separate target is limited. Therefore, spectral classes are initially assessed as surfaces similar to the reference sample and are associated with a lithological unit after field verification (NASA/Jet Propulsion Laboratory, n.d.-a; NV5 Geospatial, n.d.-b).

A surface matching the reference spectrum of an altered intrusive rock is of interest for geological investigation, but such a match alone does not confirm mineralization or metal content. Reliable interpretation requires examination of the rock's mineral composition, alteration type, and geochemical characteristics. Accuracy assessment requires independent points that were not used to create the reference spectra, with falsely detected and missed targets recorded separately.

Conclusions. The spectra of the SP-1 gabbro-diabase, SP-2 altered intrusive rock, and SP-3 granite samples collected from the Vaxshivar site were compiled in ENVI as a local reference set. Qualitative analysis of the spectral curves revealed differences in their shape and relative amplitude. These reference spectra can be used for targeted searching for similar surfaces in ASTER imagery.

Important requirements for linking field spectra to satellite imagery include placing reflectance values on the same scale, matching reference spectra to sensor bands, and controlling image quality. Targets discriminated using the Target Detection Wizard module in ENVI are mapped in association with the field sample codes.

The geological reliability of the results is assessed through independent field observations and the necessary laboratory analyses.

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