SPECTRAL REFERENCE LIBRARY FILLED WITH REFLECTANCE ROCK FEATURES

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ABSTRACT. Remote sensing is applied often in Earth observations. It includes acquiring, processing, and interpreting images and multispectral data, acquired from optical sensors mounted on airborne and satellite platforms. For better object-oriented interpretation of remotely sensed data the reference spectral features of well-described objects are required from laboratory, field, and satellite sensors. In-situ laboratory and field remote sensing measurements provide a significant part of the spectral data for interpreting spectral images with different spatial resolution and creating thematic spectral reference libraries. Including data from different experiments into an accessible reference spectral library ensures their continued exploitation, provides a basis for their qualitative assessment, and allows them to be exchanged between specialists from different research and applied sciences. Creating, updating and maintaining a spectral reference library requires periodic laboratory and field experiments, including spectrometric and other type of measurements, in this case, of rocks. The reflectance rock features are used for updating regularly the library with the necessary information. This study suggests that collected spectral data from the field spectrometric measurements of the different exposed rocks and laboratory spectral measurements of the samples collected in the field campaign will be used for filling in the reference spectral library. The obtained spectral reflectance features could be used in airborne and satellite image classification and for comparison with reference reflectance spectra from other spectral libraries. To obtain the data for filling in the presented spectral reference library, spectrometric systems, assembled in the Department of Remote Sensing Systems at the Space Research and Technology Institute of the Bulgarian Academy of Sciences, based on models of Ocean Optics spectrometers Inc. were used. The spectrometric system TOMS /Thematically Oriented Multi-Channel Spectrometer/ was used to perform laboratory and field spectrometric measurements. Field spectrometric measurements were performed during petrology training on established geological routes. Laboratory spectrometric measurements were performed in the Spectral and Photometric Measurements Laboratory of the Remote Sensing Systems section. The resulting reflecting spectra can be used to classify satellite images and compare them with the reference reflection spectra from other spectral libraries.

Keywords: Earth and planets remote sensing, Earth observations, laboratory and terrain spectrometric measurements, spectral data, spectral library

СПЕКТРАЛНА РЕФЕРЕНТНА БИБЛИОТЕКА ЗАПЪЛНЕНА С ОТРАЖАТЕЛНИ ХАРАКТЕРИСТИКИ НА СКАЛИ

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РЕЗЮМЕ. Известно е, че за изучаване на планети, се използват различни дистанционни методи на изследване. Също така, при наблюденията на Земята дистанционните изследвания са често използвани. Те включват процесите на получаване, обработка и интерпретация на изображения и многоканални спектрални данни, регистрирани от оптични сензори, които са монтирани на самолетни и спътникови платформи. За повишаване на точността при обектно-ориентирана интерпретация на данните от дистанционните изследвания на изучените и добре описани обекти се изисква провеждането на измервания на еталонни спектрални характеристики, които се получават от лабораторни, полеви и спътникови сензори. Лабораторните и полеви дистанционни измервания осигуряват значителна част от спектралните данни за интерпретиране на спектрални изображения с различна пространствена разделителна способност и за създаване на тематични спектрални референтни библиотеки. Включването на данни от различни експерименти в достъпна референтна спектрална библиотека гарантира тяхната продължителна експлоатация, осигурява основа за тяхната качествена оценка и позволява получените данни да се обменят между специалисти от различни научни и приложни области. Създаването, актуализирането и поддържането на референтна тематична спектрална референтна библиотека изисква периодични лабораторни и полеви експерименти, включително спектрометрични и други видове измервания на отдлени обекти на изследване, в конкретния случай - на скали. Спектралните отражателни характеристики на скали се използват за редовно попълване на създаваната библиотека с необходимата информация. Такъв вид изследване предполага измерването на спектрални отражателни характеристики на скали при теренни експерименти на различни скални разкрития и провеждане на лабораторни спектрометрични измервани на скални образци, събрани от местата на провеждане на теренните измервания. В настоящия доклад авторите представят етапите за получаването на данните, генерирането на спектралната референтна библиотека във вид на база от данни и запълването й с получените спектрални отражателни характеристики на скали. За получаване на данните, с които ще бъде запълнена представената спектрална референтна библиотека, са използвани спектрометрични системи, асемблирани в секция „Системи за дистанционни изследвания" в Института за космически изследвания и технологии към Българска академия на науките, базирани на модели на спекрометри на Ocean Optics Inc. Със спектрометричната система TOMS /Thematically Oriented Multi-channel Spectrometer/ са проведени лабораторни и полеви (теренни) спектрометрични измервания. Теренните спектрометрични измервания са реализирани по време на учебни практики по петрография по утвърдени геоложки маршрути. Лабораторните спектрометрични измервания са осъществени в лаборатория „Спектрални и фотометрични измервания" към секция „Системи за дистанционни изследвания". Получените отражателни спектри могат да се използват за класификация на спътникови изображения и да се сравнят с референтните отражателни спектри от други спектрални библиотеки.

Ключови думи: дистанционни изследвания на Земята и планетите, наблюдения на Земята, лабораторни и теренни спектрометрични измервания, спектрални данни, спектрални библиотеки

Introduction

The in-situ reference spectral data are very important in Earth observations for supporting mineral exploration and mapping geology, for recognizing minerals and rocks by their spectral signatures, and for the future planning of satellite missions. Remote sensing measurements made in laboratory and on the field (in-situ) provide helpful information for research studies and for analyzing data from sensors located on airborne and satellite platforms. Analysis of spectral data obtained in the laboratory and on the field, and from various other platforms, requires a knowledge base that consists of different spectral features for known and well-described different objects.

The U.S. Geological Survey (USGS) spectral library is the biggest one and is related both to Earth observations and spacecraft mission planning (Kokaly et al., 2017). The USGS spectral library presents a knowledge base for the characterization and mapping of materials and provides important compositional standards. As part of the spectral library and at the same time as independent thematic spectral libraries the Jet Propulsion Laboratory (JPL) (https://speclib.jpl.nasa.gov/documents/jpl_desc, July 2018), John Hopkins University (JHU) (https://speclib.jpl.nasa.gov/documents/jhu_desc, July 2018), Arizona State University (ASU) (http://tes.asu.edu/spectral/library/index.html, July 2018), the ASTER/ECOSTRESS projects (https://speclib.jpl.nasa.gov/, July 2018), collect spectral data from laboratory and field spectrometric measurements. The JPL and JHU libraries contain reflectance spectra, the ASU library contains emittance spectra and the ASTER library contains both of them. Another spectral library for the storage of spectrometer data and associated metadata is the SPECCHIO spectral database system (Hueni et al., 2011). Spectroscopic data are also acquired at the Keck/NASA RELAB (Reflectance Experiment Laboratory) supported by NASA as a multi-user spectroscopy facility (http://www.planetary.brown.edu/relab/, July 2018) and these data are used for filling in the RELAB Spectral Database (http://www.planetary.brown.edu/relabdocs/relab_disclaimer.htm, July 2018)

For processing the spectral data from the ASTER Spectral Library and the ENVI Spectral Libraries Spectral Python (SPy) a pure Python module is used. SPy is free, open source software distributed under the GNU General Public License (http://www.spectralpython.net/, July 2018). Thematic spectral libraries in ENVI software could be created using the Spectral Library Builder from a variety of spectra sources, including ASCII files, spectral files produced by spectrometers, other spectral libraries, and spectral profiles and plots. The collected spectra are automatically resampled to an input wavelength space using Full-Width Half-Maximum /FWHM/ information (https://www.harrisgeospatial.com/docs/spectrallibraries.html, July 2018). In the RELAB the Modified Gaussian Model (MGM) software is used (http://www.planetary.brown.edu/mgm/, July 2018).

The USGS spectral library contains information about spectral features and characteristics mainly of minerals and rocks but also of soil and vegetation. Based on the specifics of the researched object, thematically oriented spectral libraries started to be created (Ruby and Fischer, 2002; Fang et al., 2007; Rivard et al., 2008).

The thematic spectral libraries have a significant application in the integration of in-situ measured spectra and specific properties of the studied objects and remotely sensed spectral data (Tits et al., 2013). Applications of the spectral libraries using various methods for processing and interpreting of spectral data have been made (Rivard et al., 2008; Xu et al., 2018).

Laboratory and field spectrometric measurements of rocks have been continuing for more than 30 years performed by different teams from the Space Research and Technology Institute at the Bulgarian Academy of Sciences /SRTI-BAS/. The authors of this study aimed to collect spectral data both from previous own experiments (Avanesov et al., 1989; Borisova, 2002, 2003, 2004, 2013, 2015; Borisova and Kancheva, 2005; Борисова, 2007; Борисова и др., 2008, 2009; Borisova and Iliev, 2008; Borisova et al., 2009, 2010; Borisova and Petkov, 2014), from colleagues' previous experiments with their agreement (Spiridonov and Chervenyashka, 1984; Lukina et al., 1992; Kancheva, 1999; Stoimenov et al., 2014) and from new ones in order to create a reference thematic spectral library filled with reflectance rock features. It consists of spectral data with metadata and additional information for better interpretation of spacecraft images with different spatial resolution.

The reflectance spectra of representative samples of magmatic rocks from different regions in Bulgaria (Rila Mountain, Stara Planina Mountain, Sredna Gora Mountain) are studied as an example in the present paper. The study proposes collected spectral data from field spectrometric measurements of different rocks and from laboratory spectrometric measurements of the samples collected during the same field campaigns to be used for filling the reference spectral library. For easy access to the spectral library without specialized programs, simple text versions of the spectral data, their visualizations, and text files in HyperText Markup Language (HTML) format with the metadata and additional information are planned to be used. The authors aim to offer the possibility for using the spectral data to specialists working in different research and applied sciences following the procedures for accessing the spectral library and downloading the spectral data.

Materials and Methods

The information for the proposed spectral library will include description of: field and laboratory spectrometric instruments; short petrographic description of the region and studied objects (in this case – rocks); field and laboratory spectrometric measurements.

Field and laboratory instruments

The spectrometric measurements of rock reflectance spectra are performed using laboratory and field spectrometer. The used spectral instrument works in the wavelengths covering the spectral ranges from the visible /VIS/ to the near infrared

/NIR/. The spectrometer used to measure reflectance rock spectra for filling in the reference spectral library is based on models of Ocean Optics Inc. covering the spectral range from 400 to 900 nm. Spectrometric measurements of representative samples of rocks are made in laboratory and field conditions. In some cases, samples were purified, so that the unique spectral features of the studied objects could be related to their typical structure. The field reflectance spectral signatures were obtained with a TOMS /Thematically Oriented Multi-channel Spectrometer/ assembled at the Remote Sensing System Department at SRTI-BAS in collaboration with Alabama State University, USA (Petkov et al., 2005).

In the spectral libraries each spectral characteristic has a description, called also metadata, associated with the obtained spectrum. The metadata describe what was measured and can include details about the measurements made and other supporting information about the nature and composition of the studied object.

Short petrographic description

The area of the locality Kirilova polyana (Rila Mountain) consists of high-grade metamorphic rocks, metamorphosed ultrabasic and basic igneous rocks, called South Bulgarian granitoids, aplite-pegmatoid granites and fine-grained biotite granites. (Димитрова, 1960; Кожухаров, 1984; Kamenov et al., 1999)

Spectrometric studies were made of the fine-grained biotite granite. They expose near Kirilova polyana in the west direction and form the Monastic Body. Fine-grained biotite granites are light gray with massive structure and hypidiomorphic texture. The rock-forming minerals are magmatic K-feldspar, quartz, plagioclase, biotite and zircon and secondary - sericite, chlorite and clay minerals (Банушев и др., 2012).

On the road to the village Barziya, about 3 km after the Petrohan pass in Stara Planina Mountain, are revealed magmatic rocks from the Petrohan pluton. It is a complex magma body emplaced into rocks of Berkovska and Dalgidelska groups. It is made of several magmatic phases: the first is gabbro, widespread in the northern part of the pluton near Berkovitsa; the second is represented by diorites, and the third - by granodiorites. The largest areas are occupied by diorites and granodiorites. (Чунев и др., 1965; Хайдутов, 1979; Хайдутов и др., 2012)

Field spectrometric studies have been made of the diorites. They are gray, grey-greenish, medium-grained, and uniform-grained. Their structure is massive, and the texture – prismatic granular. The main rock-forming minerals are plagioclase (andesine) and amphibole, secondary – biotite and augite, and accessory - titanite and magnetite (Банушев и др., 2012).

About 10 km south of the town Zlatitsa in Sredna Gora Mountain on the road to Panagyurishte, outcrop of the South Bulgarian granitoids is embedded in metamorphic rocks of the Prarodopska group. To the South there are Bulgarian granitoids intrusive bodies of Palaeozoic age, of different sizes and composition, divided into three intrusive complexes. The first set includes intrusive granites, granodiorites and small bodies of diorite and quartz-diorites. In this complex the Smilovenski, Hisarski and Poibrenski plutons are included. The composition of the second intrusive complex includes amphibole-biotite, biotite and light granites. The Koprivshtenski, Klisurski and Matenishki plutons belong to this complex. The third intrusive complex is represented by granular biotite, biotite-muscovite and pegmatite granitoids. The Strelchenski, Karavelovski, Lesichovski and Varshilski plutons are presented in this complex. (Дабовски и др.., 1972; Мурбат и Загорчев, 1983; Загорчев и Мурбат, 1986; Peycheva et al., 2004)

At the point of the field measurement biotite granites of the Northwest Koprivshtenski pluton are revealed. They are light gray, sometimes rusty colored by iron hydroxides, medium-to coarse-grained, with a clear lineal porphyroid parallelism. They are formed by K-feldspar, plagioclase, quartz, biotite, apatite and zircon (Банушев и др., 2012).

Field and laboratory measurements

The results from the terrain spectrometric measurements of pure surface of granites, granodiorites and diorites in the Mountains of Rila, Stara Planina and Sredna Gora in Bulgaria for the period 2007-2017 will be used for filling in the reference thematic spectral library. As a result of these measurements spectral features of the investigated objects will be acquired. The obtained data are processed statistically, and the registration of 100 spectra and their average values is set in the company software used on the spectrometer.

The reference spectral library will also include data from laboratory measurements. The laboratory spectrometric measurements using the TOMS spectrometer are performed by the Remote Sensing Systems Department at SRTI-BAS. The reference spectral library will be filled in with reflectance rock features.

Example of the structure and content of the presented spectral reference library

Spectral data

Since this will be a spectral library, first come the spectral data, i.e. the results from the spectrometric measurements, both on the field and in the laboratory, for filling in the proposed spectral reference library.

The results of the performed laboratory and field spectrometric measurements are presented as text files containing description of the measured rocks in the presented example: granite, granodiorite and diorite. These spectral data are visualized as plots of spectra. The examples of the spectral reflectance signatures as a result of the laboratory and field measurement are shown on Figure 1 (a,b).

Metadata

The next information needed for filling in the proposed spectral reference library is the metadata.

The metadata include information about each measurement such as: dark spectrum, reference spectrum, number of sampled component spectra, integration time, spectra averaged, correction for electrical dark, number of pixels in processed spectrum, etc. The description of each studied object is also included. Petrographic description of each rock sample, chemical composition of minerals, etc. are given for the presented example. The metadata will be presented in separate text files.

Additional information

In some cases it is possible to collect more information for filling in the proposed spectral reference library called additional information.

The photographs of the studied objects could also be added in the reference spectral library. The photos will be included as files in related image formats (.jpg, .gif).

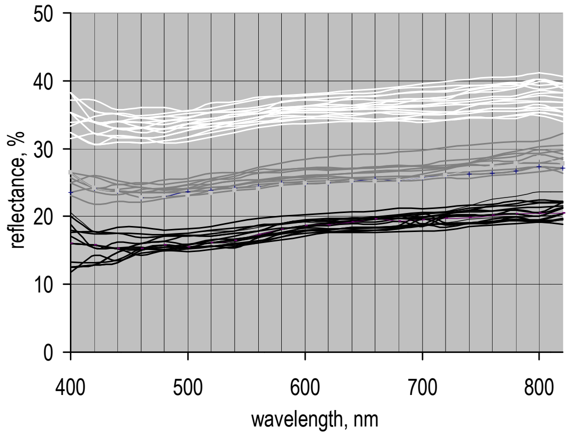


Fig. 1a. Plot of spectral reflectance signatures of granites (white line), granodiorites (grey line) and diorites (black line) acquired during the laboratory measurements.

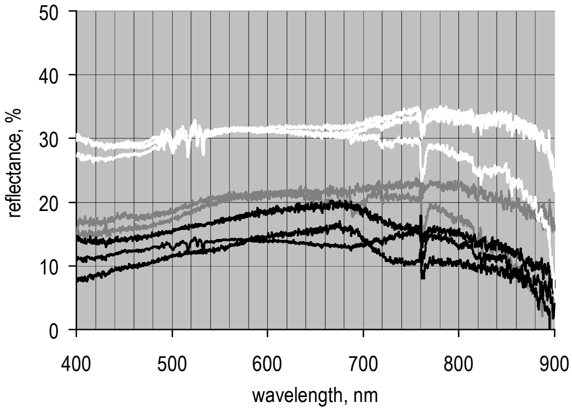
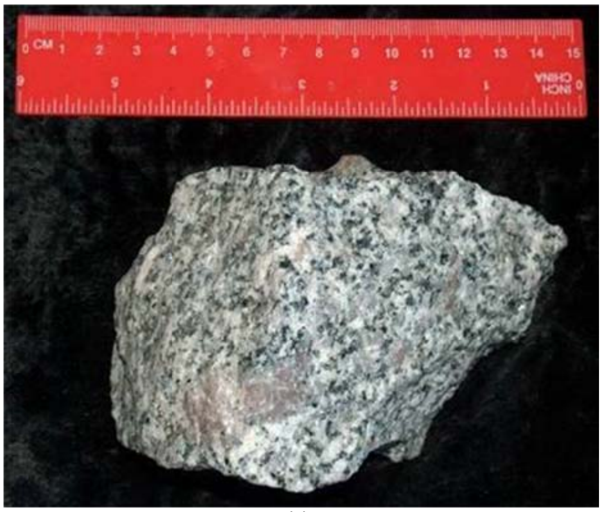


Fig. 1b. Plot of spectral reflectance signatures of granites (white line), granodiorites (gray line) and diorites (black line) acquired during the field measurements (all on pure rock surface).

Samples of granite (a,b) studied in the laboratory are presented on Figure 2. Photos of the granites studied in some field measurements are shown on Figure 3.



(a)

(b)

Fig. 2. Porphyroid granites (a, b) from Sredna Gora Mountain, Bulgaria.

(a)

(b)
Fig. 3. Granites in (a) Sredna Gora and (b) Rila Mountains in Bulgaria.

The main aim of the performed spectrometric measurements is to acquire and collect spectral data, in this case - about rocks, for the creation of a specialized thematic reference spectral library and the possibility for exchanging information between existing open access spectral libraries.

Conclusions

In-situ laboratory and field spectrometric measurements provide a significant part of the spectral data for interpreting spectral images with different spatial resolution and in creating thematic reference spectral libraries, in this case – of rocks. Including data from different experiments into an accessible spectral library ensures their continued exploitation, provides a basis for their qualitative assessment, and allows them to be exchanged between specialists from different fundamental and applied sciences. Therefore, it is necessary to have the possibility for complementing the spectral libraries in short periods of time depending on the subject of the survey. Creating, updating and maintaining a reference spectral library requires periodic laboratory and field experiments, including spectrometric and other type of measurements.

At the same time, laboratory and field spectrometric measurements are part of an integrated system for Earth and planets remote sensing and ground observations. In-situ spectrometric measurements have potential for long-term practical application when used to verify data which increases their accuracy. This leads to an optimal correlation between the different methods for measuring and observing the different types of land cover: soils, vegetation, water, rocks, minerals, etc. The creation of a spectral library increases the effectiveness of scientific research in the field of remote sensing on the Earth's and planets' surfaces, creates synergy between different scientific fields and helps the exchange of information.

For future work, the authors suggest collecting field reflectance spectral features of different rocks and laboratory spectrometric measurements of the samples collected in the field campaign. The obtained spectra could be used for airborne image classification and comparison of the results with the reference spectra of the USGS and other spectral libraries.

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