Влияние минерального состава гранитов на измеряемые спектры яркости

Д.С. Борисова, Р.Х. Кынчева

Центральная лаборатория солнечно-земных воздействий
Болгарская академия наук,
Болгария София 1113 ул. Акад. Г.Бончев, бл. 3
E-mail: dborisova@stil.bas.bg; rumik@abv.bg

Граниты являются определяющим компонентом континентальной земной коры, формируя ту сушу, на которой мы живем и в пределах которой сосредоточено большинство доступных для разработки месторождений полезных ископаемых. Граниты на 90% состоят из равных долей кварца, плагиоклаза и калишпата, к которым в небольшом количестве (5-7%) добавляются магнезиально-железистые силикаты, называемые темноцветными минералами. Несмотря на постоянство соотношений первых трех главных минералов, именуемых салическими, граниты очень разнообразны в составе темноцветной части: широко представлены в природе биотитовые, роговообманковые, диопсидовые, гиперстеновые, двуслюдяные граниты, известны и более экзотические разновидности. Если добавить к этому вариации в составе плагиоклаза (Ca-Na-полевого шпата), взаимной смесимости натрового и калиевого полевых шпатов, степени их структурной упорядоченности, то количество видов гранита, различающихся минеральным составом, будет намного более сотни. Но при всех вариациях состава гранит всегда остается гранитом.

Для изучения столь большого разнообразия гранитов способствует и дистанционное зондирование Земли, в частность полевые и лабораторные спектрометрические методы. Настоящий доклад посвящен исследованию влияния минерального состава гранитов на измеряемые спектры яркости, для чего проведено спектрометрирование гранитов в лабораторных условиях в диапазоне 0,5-1,1 мкм. Для анализирования полученных данных использованы методы декомпозиции спектральных смесей, "почвенная линия" на плоскости NIR-Red, регрессионный угол наклона зависимости стойности спектрального отражения от длины волн и индексы-отношения яркостей спектральных каналов.

Работа выполнена при поддержки проектов НСНИ-МОН №НЗ-1410/04 и №МУНЗ-1502/05.

Introduction

The spectrometric measurements are a part of remote sensing and they could be used as an additional opportunity to derive significant information about petrography and mineralogy. Real land covers are mixtures of materials and the theory of the mixed spectral classes [1] is an efficient method to study various rocks and minerals. Granites are two sub-classes of one and the same class (group) of granite and rhyolite [2]. For remote sensing the granites are mixed class of their rock-forming minerals.

The goal of the present paper is the study the behaviour of the granite reflectance spectra depends to their rock-forming minerals.

Methods and materials

It is well known the specific reflectance, absorption and emission of solar radiation by land covers are the basis of remote sensing, of spectrometric measurements in particular [3, 4].

In the reflected by the petrographic object radiation holds the mineralogical information. Containing this information the reflectance spectra $R\{r(\lambda_i)\}$ present the spectral informational features of the studied object. The parameters of studied object based on measured spectral reflectance $R\{r(\lambda_i)\}$ could be defined. The dependence of the reflectance signatures behaviour to type and rock-forming minerals of the granites provides a basis for the purpose.

Mineral content of the studied objects is of particular importance. It determines the distribution of reflected from surface radiation. The amount of reflected light is dependent on mineral content [5-7]. As the rock-forming minerals darker, more light is absorbed and the reflectance drops. The reflectance increases as the content of the salic minerals increase.

Made literature review shows that previous investigations aim to analyzed mineral samples [4] and in some papers rock samples are investigated [7-9]. In present paper granites as mixed class of their rock-forming minerals are examined and obtained results are analyzed. For the analysis different approaches are applied: spectral mixture decomposition, rock baseline, reflectance curves inclination angles, ratio indices.

The studied rock samples of granites are with different proportion of mafic (biotite, amphibole) and salic (quartz, potassic felspar, plagioclase felspar, muscovite) rock-forming minerals in total mixture.

If a priori information is not enough it could be bring a lot of omissions in interpretation. It is important to know technical parameters of used device and experimental conditions.

Laboratory spectral reflectance measurements in range (550 - 1100 nm) with $\Delta\lambda$=10 nm of granites (15 samples) are performed. For this purpose the spectrometric system for remote sensing investigations, made in STIL-BAS, is used [10].

Results and discussion

Figure 1 shows the reflectance spectra of the granite samples. The reflectance feature of the coarse-grained granites (dot-dot line) is almost horizontal or with a small angle ((0-15), of the medium-grained granites (dash line) the angle is 15-30 and of the fine-grained ones (solid line) the slope is over 30 [11]. For lighter granites which content of salic minerals is more than content of mafic minerals reflectance values are higher [12].

Plot of NIR = 1.00 μm versus red = 0.62 μm reflectance for laboratory reflectance spectra are presented in Figure 2. The rock baseline is established with linear regression:

NIR = 1.077 (red) + -0.52, R^2 = 0.97, n=15.

When the red and NIR reflectance values are used all granites fall on a well-defined rock line by analogy with "soil line".

The granites are divided into three groups based on the quantitative assessment of the rock-forming salic and mafic minerals. The mineralogical analysis is carried out in University of Mining and Geology - Sofia by assistant professor B. Banoushev. These three groups form three clusters in 2-D space of NIR-Red reflectance (Figure 2). The granites with lowest content of salic minerals are marked on the Figure 2 with fill points, for the medium content respectively with thick points and for the highest content values – with thin points (Table 1). The NIR-Red relation is used in stage of the differentiation of different type land covers because of high accuracy of obtained results.

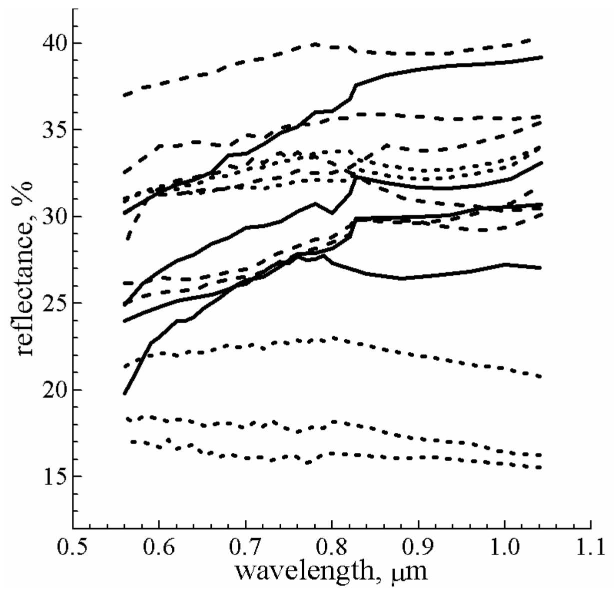

Figure 1. Spectral reflectance features of the three types granites: the coarse-grained - dot-dot line, the medium-grained - dash line and the fine-grained - solid line

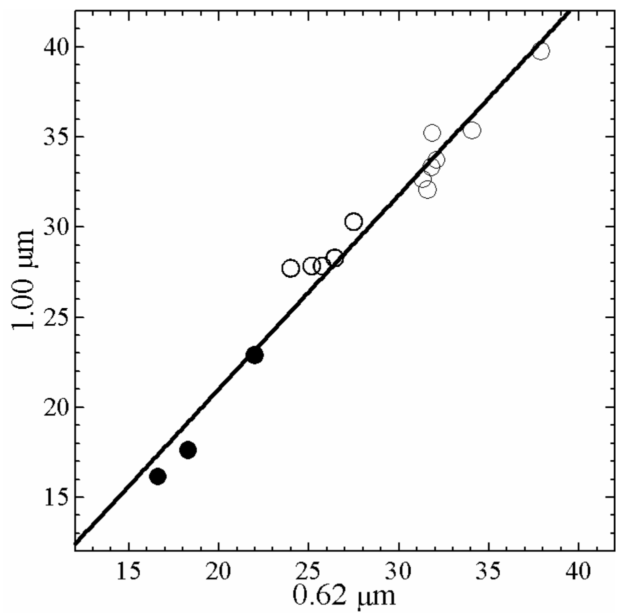

Figure 2. Plot of NIR vs. red reflectance

In Table 1 the description of the studied granite samples and of the content of the salic and mafic minerals are presented.

Table 1. Content of salic and mafic minerals in granites

No	*Name*	*Salic*	*Mafic*
1	Granite	90	10
2	Porphyry granite	75	25
3	Porphyry granite	85	15
4	Two-mica granite	95	5
5	Porphyry granodiorite	60	40
6	Granite	83	17
7	Granite	75	25
8	Granite	90	10
9	Granite	80	20
10	Granite	75	25
11	Alkalic granite	40	60
12	Granite	75	25
13	Granite	70	30
14	Granite	85	15
15	Granodiorite	40	60

In Figure 3a and Figure 3b dependence between the content of salic and mafic minerals in the granites and the reflectance at 0.76 μm are shown. With increasing of the salic minerals the reflectance values increase and vice versa in the case of predominating of the mafic minerals the reflectance values decrease. The empirical regressions are applied for assessing the influence of the salic respectively mafic minerals on the obtained spectral reflectance data at 0.76 μm.

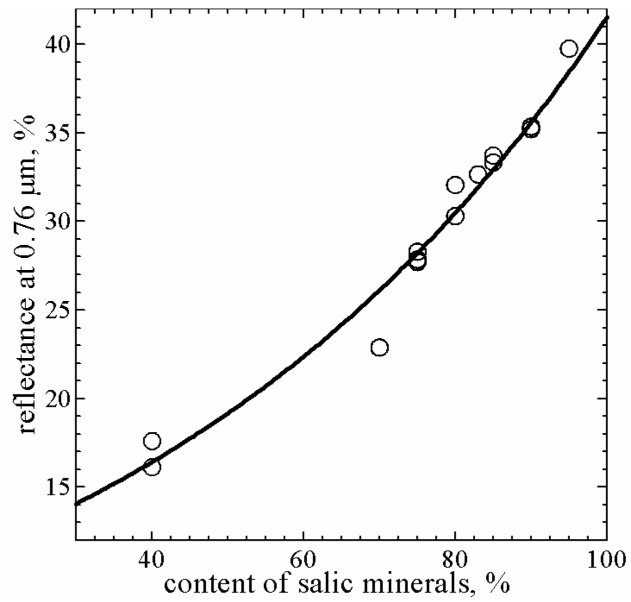

Figure 3a. Relationships between the content of salic minerals in the granites and the reflectance at 0.76 μm

Equation of the applied exponential regression is:

NIR = exp(0.0154676 * X) * 8.84346,

Number of data points used n = 15

Coefficient of determination, $R^2 = 0.97$

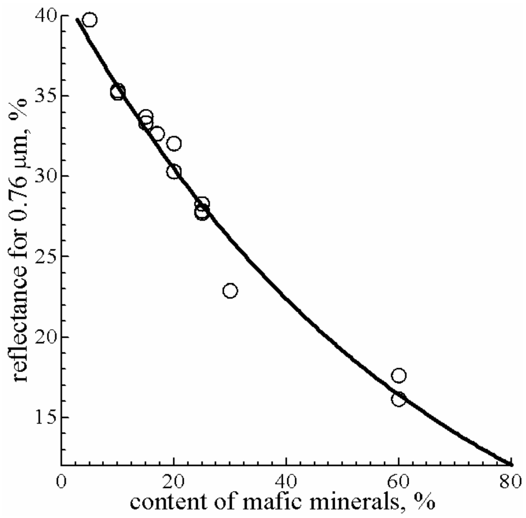

Figure 3b. Relationships between the content of mafic minerals in the granites and the reflectance at 0.76 μm

Equation of the applied exponential regression is:
NIR = exp(-0.0154676 * X) * 41.5309
Number of data points used n = 15
Coefficient of determination, R^2 = 0.97

Figure 4 demonstrates the connection between the content of salic and mafic minerals in granites and the reflectance spectra inclination angles. The larger quantity of salic rock-forming minerals enhances the inclination of reflectance signatures (see Figure 4a). If the mafic rock-forming minerals prevail over salic ones (Figure 4b) the reflectance does not increase and spectra angle is very small. The empirical regressions are used for analyzed the influence of the salic respectively mafic minerals on the inclination of the obtained spectral reflectance curves.

Equations of the used exponential regressions (Figures 4a and 4b) are:

Y = exp(0.0495382 * X) * 0.449704
Number of data points used n = 15
Coefficient of determination, R^2 = 0.8
and
Y = exp(-0.0495382 * X) * 63.7299
Number of data points used n = 15
Coefficient of determination, R^2 = 0.803278

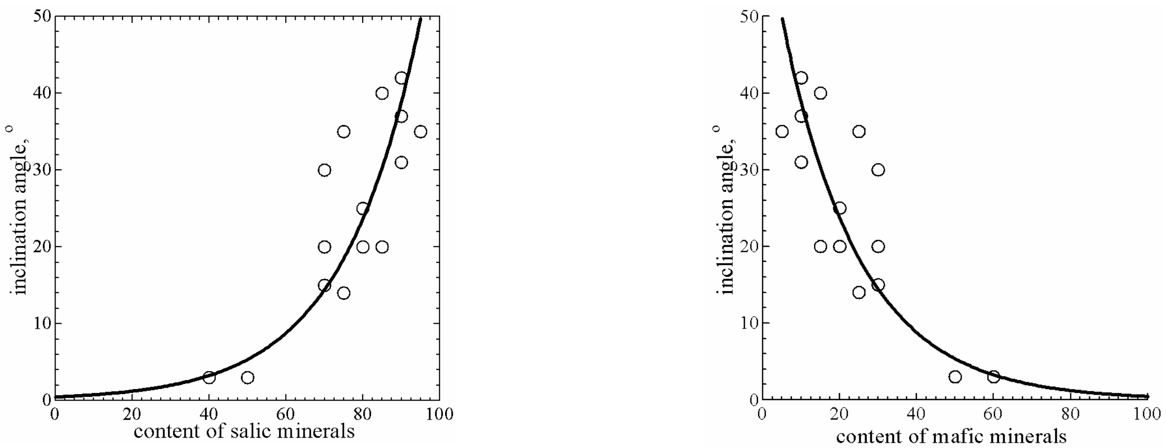

Figure 4. Relationships between the content of salic and mafic minerals in granites and reflectance curves inclination angles

Figure 5 shows the interaction between spectral transformation (index) NIR (λ = 0.76 μm)/R (λ = 0.62 μm) and the quartz content as one of the salic minerals. The enhancing of the quartz content lead to the index values increase.

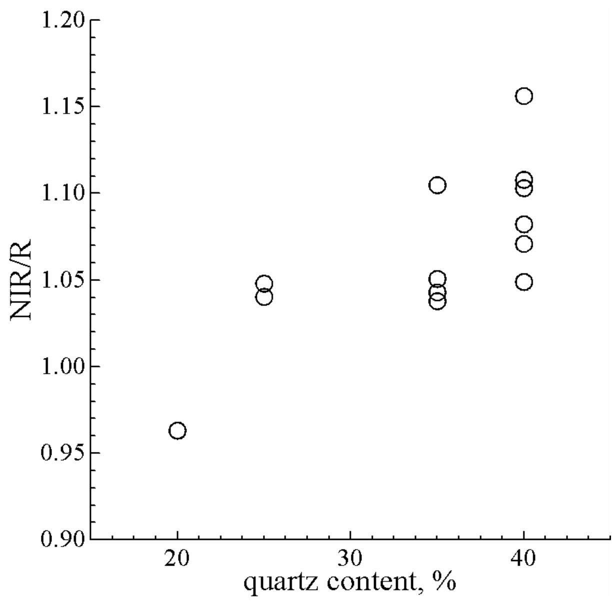

Figure 5. Relations between the quartz content and the spectral index NIR/R

The next dependence is based on the content of widespread iron in rock-forming minerals in great number of rocks. It could be used for the rock and mineral recognition. The iron absorption at 0.8 μm is reduced in depth according to it content. The 0.9-μm-absorption line shifts position with elements substituted for iron [4]. The minimum reflectance values at 0.8 μm become smaller with the increasing of the iron content

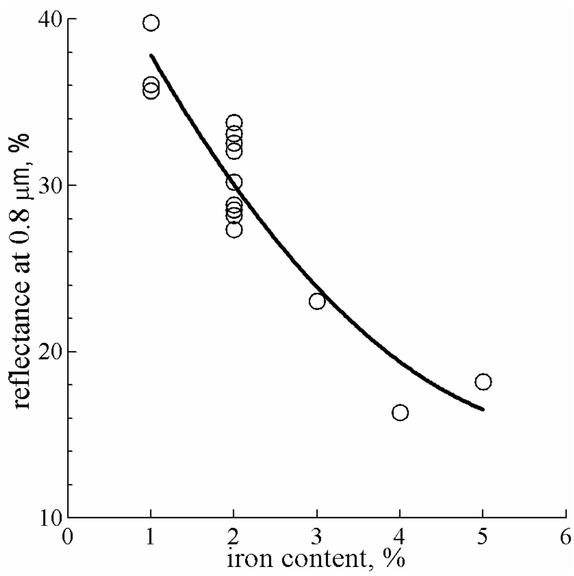

Figure 6. Relations between the iron content and the reflectance at 0.8 μm

Equation of the used exponential regression (Figures 6) is:

$Y = 47.2568 + -10.2473*X + 0.820235*X^2$

Number of data points used n = 15

Coefficient of Determination R^2 = 0.87602.

CONCLUSIONS

An advantage of spectrometric investigations is a lot of information including in obtained results. This allowed their use as decode indication for type classification of studied objects.

Analyzed reflectance spectra content complex information. Their types depend on set of factors (color, determined in mixed class granites by proportion of salic and mafic rock-forming minerals; structure and roughness of the samples). It can conclude that granite reflectance spectra behavior depends to:

- chemical composition of rock-forming minerals;
- color of rock-forming minerals grouped as salic and mafic ones;
- proportion of salic and mafic rock-forming minerals in granites.

Future detailed spectral data analysis including other methods (ratio indices, continuum removal) for studying granites as mixture of rock-forming minerals is intended.

Acknowledgments The Bulgarian National Science Fund under Contracts NZ-1410/04 and MUNZ-1502/05 supported this study.

References

1. *Mishev D.* Spectral Characteristics of Natural Objects // Sofia, Publ. House Bulg. Acad. of Sci., 1986. 150 p.
2. *Маринов Т.* Петрография // София, изд. Техника, 1989. 244 с.
3. *Мишев Д., Добрев Т., Гугов Л.* Дистанционни методи в геофизиката и геологията // София, изд. Техника, 1987. 272 с.
4. *Clark R.* Chapter 1: Spectroscopy of Rocks and Minerals and Principles of Spectroscopy // Manual of Remote Sensing, (A.N. Rencz, ed.) John Wiley and Sons, New York, 1999. P. 3-58.
5. *Clark R., T. Roush.* Reflectance spectroscopy: Quantitative analysis techniques for remote sensing applications // J. Geophys. Res., vol.89, 1984. P. 6329-6340.
6. *Hapke B.* Introduction to the Theory of Reflectance and Emission Spectroscopy // Cambridge University Press, New York, 1993. P. 278.
7. *Spiridonov H., A. Krumov, K. Katzkov, S. Yovchev.* Measurement Results and Conclusions on the Spectral Reflective Coefficients of Volcanites, Granitoides and Gneisses // Remote Sensing and Mineral Exploration, Pergamon Press, Oxford and New York, 1980. P. 157-163.
8. *Spiridonov H., A. Krumov, K. Katzkov, S. Yovchev.* Measurement results and conclusions on the spectral reflectance coefficients of volcanites, granitoides and gneisses // Space Research in. Bulgaria, 4, 1983. P. 59-69.
9. *Clark R., G. Swayze, A. Gallagher, T. King, W. Calvin.* The U. S. Geological Survey, Digital Spectral Library: Version 1: 0.2 to 3.0 um, U.S. Geological Survey, Open File Report 93-592, 1993. P. 1326.
10. *Илиев И.* Спектрометрична система за слънчеви и атмосферни изследвания // Електротехника и електроника, 3-4, 2000. С. 43-47.
11. *Borisova D.* Spectrometric Measurements of Granites and Study of Surface Effects // Annual U M G, 2003, vol.46, Part I: Geology and Geophysics. P. 327-329.
12. *Борисова Д.* Отражателни характеристики на основните видове скали и тяхното спектрометрично изучаване // III Нац. конференция с международно участие по съвременни проблеми на слънчево-земните въздействия, София, 1996. С. 45-47.