

## DETECTION OF OPEN PIT MINES AND DUMP AREAS BASED ON LAND COVER THERMAL MAPPING

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**ABSTRACT.** Ferrous and non-ferrous open pit mining and waste dumped are result of a human activity and are the largest pollutants for certain regions in Bulgaria. Since in the most of the open pits the mined substance is stone we suggest the remote investigations in such area to be carried out in the thermal range (8-12  $\mu\text{m}$ ) of electromagnetic spectrum. The data used during our study consists of laboratory measurements and airborne data. After data processing and interpretation, areas into which reclamation activities have been made, could be easily determined. These results support the assessment of the human impact on the ecological status in contaminated by mining actions regions. Obtaining more reliable results is expected by the recently launched instruments with higher spatial resolution (less than 20 m).

### ИДЕНТИФИКАЦИЯ НА ОТКРИТИ РУДНИЦИ И НАСИПИЩА ВЪЗ ОСНОВА НА ТЕРМАЛНО КАРТИРАНЕ НА ЗЕМНАТА ПОВЪРХНОСТ

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**РЕЗЮМЕ.** Железните и не-железни открити рудници и струввания на отпадъци са резултат от човешката дейност и са основните замърсители за определени райони в България. Тъй като в повечето открити рудници добиваният материал е скала, ние предлагаме дистанционните изследвания в тези райони да се извършват в топлинния инфрачервен диапазон (8-12  $\mu\text{m}$ ) на електромагнитния спектър. При нашите изследвания са използвани лабораторни измервания и спътникови данни. След тяхната обработка и интерпретация, зоните в които е извършвана експлоатационна дейност могат лесно да бъдат определени. Резултатите от тези проучвания допълват оценката на човешките въздействия върху екологичния статус на замърсените от минни разработки райони. Нововъведената апаратура, с по-висока разделителна способност (по-малко от 20 m), се очаква да доведе до по-надежни резултати.

### Introduction

Spectral mixture analysis has as one of the basic objective the definition of subpixel (subclass) proportions of spectral endmembers (classes) which are related to mappable surface constituents. Spectral mixture analysis decomposes the mixed pixel determining the fractions of each spectral endmember which combine to produce the mixed pixel's spectral signature. The spectral signature of the pixel is a combination (linear or non-linear) of the spectral signatures of the component surfaces. Assuming linear mixing, (the spatial fractions = the spectral fractions) we consider these fractions to be the area fractions.

Pixels containing mixed spectral information about the objects under study are commonly found in remotely sensed data. This is due to the limitations of the spatial resolution of the airborne instruments (such as Landsat, SPOT, etc.) and the heterogeneity of features on the ground. The mixture spectra are often generated when the pixel covers more than one land cover class. This mixed classes often results in poor classification accuracy when conventional algorithms such as the maximum likelihood classifier (MLC) are used. It is possible to obtain better results if the mixed pixels are decomposed into

different proportions of components. In order to solve the mixed pixel problem, scientists have developed different models to unmix the pixels into different proportions of the endmembers (Mishev, 1991; Ichoku, 1996). Spectral mixture analysis (SMA) is one of the most often used methods for handling the spectral mixture problem. It assumes that the spectrum measured by a sensor is a linear combination of the spectra of all components within the pixel.

In this paper a study on mineral and rock emissivity was conducted. Evaluated was the possibility for using recently designed thermal infrared prototype (NSFB Contract MUNZ-1201) for measuring minerals and rock samples from open pit mines and dumps. The data used during our study consists of:

- Thermal infrared spectra derived from an image of the region of interest.
- Field samples measured in laboratory.

Remotely sensed data obtained in year 2000 for a region near an opencast mine in Bulgaria are compared with laboratory multispectral measurements of rock and mineral samples performed in the thermal infrared band with multi-channel radiometers.

Sample field data were collected to describe the thermal spectral characteristics of the classes of interest in terms of land cover subclasses. The method of specifying hemispherical emissivity has been applied to manage and interpret the obtained data. Our results confirmed that successful methodology for remotely sensed data interpretation has been worked out.

## Study area

Kremikovtzi opencast is situated near the capital of Bulgaria, Sofia. The earliest ankerite generation preceded the formation of primary Mn-siderite ore in the deposit. Its occurrence in the Kremikovtzi opencast workings may be established most often by indirect criteria based on the areal distribution of yellow to yellowish-brown low-Mn limonites. (Vasileva et al., 2002) The ores in Kremikovtzi deposit have polymetallic sulphide mineralization.

Three kinds of iron ore occur in the deposit (report No274/1984, STIL-BAS):

- goethite ( $\text{Fe}_2\text{O}_3 \cdot n\text{H}_2\text{O}$ ) ore which is spread throughout the whole area of the deposit; it comprises 2/3 of all types of iron ore in the deposit;
- hematite ore is about 11% of the whole Fe-ore; it is composed mainly of the mineral hematite ( $\text{Fe}_2\text{O}_3$ ) – with an average quantity of 60%;
- siderite ( $\text{FeCO}_3$ ) ore is preserved in the deepest parts of the deposit, which are unaffected by processes of oxidation;
- barite bodies are found within the goethite or the siderite ore or right above the iron ore stocks; the content of  $\text{BaSO}_4$  in the barite bodies varies from 18% to almost monomineral accumulation.

## Materials and methods

The results in this paper are based on spectral data coming from three different sources, described as laboratory, field and airborne.

Laboratory measurements of the hemispherical emissivity of samples of goethite, hematite, siderite, barite and dolomite (5 mineral and rock samples) are carried out by means of the “box” method (Sobrino, Caselles, 1993). The emissivity is measured in spectral band 8-12  $\mu\text{m}$  with an infrared radiometer IR-1, whose normalized spectral apparatus function  $q(\lambda)$  is presented in Fig. 1 (Final Report, 1992). The hemispherical reflectance (R) of the samples is determined from the obtained data using Kirchhoff's Law ( $R=1E$ ), where E is emissivity.

Field data were collected in Kremikovtzi opencast and dump. Chemical analysis of the collected mineral samples was made to acquire the iron content. Spectral data were obtained with field instrument TOMS working in visible range of EMS. (Petkov et al., 2005)

Airborne data used in the developed models are taken from Landsat Thematic Mapper (TM) instrument acquired in June 2000. For the visual interpretation this digital image was displayed as single band images. Band TM6 (Fig. 2) was used

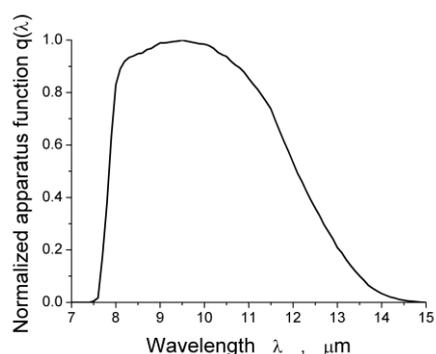


Fig. 1. Spectral dependence of the normalized apparatus function  $q(\lambda)$  of the radiometer IR-1

for comparing the data from IR-1 and field data. Dataset was formed comprising the whole image (large area) shown on Fig. 2. From this dataset only the data from the open pit and dump was extracted based on topographic map and additional field information. An illustrative example of high resolution remote sensing technique is presented in Fig. 3.



Fig. 2. Greyscale image of TM6 (high gain) of region of interest

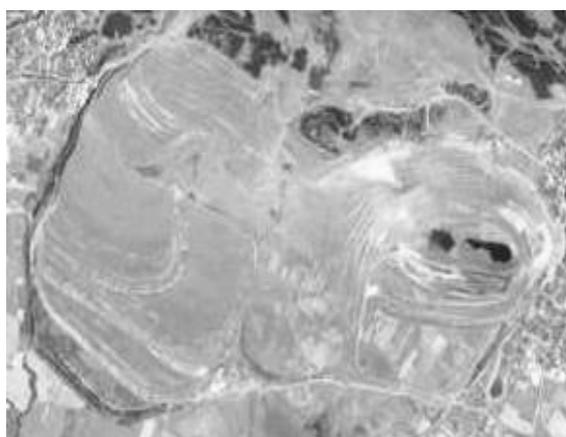


Fig. 3. Quick Bird image of study area

## Results and discussion

Data for the studied minerals obtained under laboratory conditions with IR-1 (Fig. 4) exhibit coincidence with similar data from other sources (TES, 2005). These promising results guarantee that the data from IR-1 are reliable and could be used in mineral composition investigation.

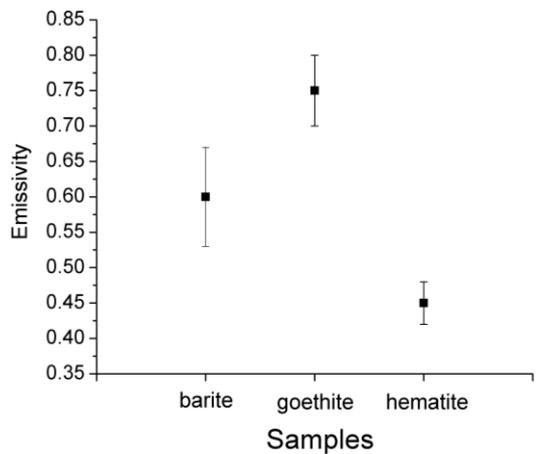


Fig. 4. Hemispherical emissivity measured by IR-1 in thermal infrared band 8-12 μm

Data for the studied rock samples obtained under laboratory conditions with IR-1 (Fig. 5) exhibit high values for bare limestone. Vegetation present in the slag dump which correlates with low emissivity values. These promising results guarantee that the data from IR-1 are reliable and could be used in rock composition investigation.

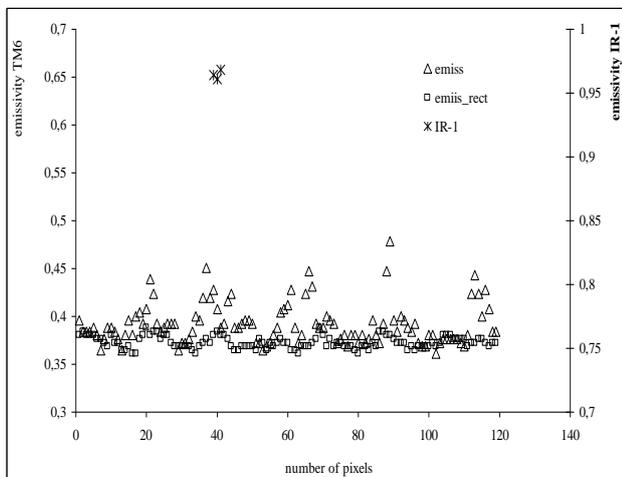


Fig. 5. Emissivity of limestone measured by IR-1 and calculated by Kirchhoff's law from TM6 (emiss – large area; emiss\_rect – slag dump)

## Conclusions

In this paper a practical approach to establish correspondence between laboratory, field and airborne measurements for ore minerals and rocks has been discussed. In our future work we shall consider more detailed models including more minerals.

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