Abstract

MINEO is a shared-cost action for Research and Technological Development contracted on January 2000 with EU DG Information Society Technologies in the frame of the Fifth Framework programme for Research and Technological Development. MINEO aims at assessing and monitoring the environmental impact of mining activities, using the most advanced Earth observation techniques, and in particular hyperspectral remote-sensing sensors.

During an airborne survey six mining areas, five within Europe and one in Greenland have been scanned by HyMap, a hyperspectral scanner build by the Australian company Integrated Spectronics.

The firsts MINEO results have shown the very high potential of hyperspectral imagery in mining-related contamination and impact mapping in various vegetated European environments, either

i) directly through mineral- and rock-mapping of the mining waste and residues and related contaminated areas; or

ii) indirectly, through the mapping of mining induced vegetation stress or contamination.

The objective of the Austrian test site “Steirischer Erzberg” was the development of combined Remote Sensing and GIS tools for mining site rehabilitation and reforestation in an Alpine environment. The first results of the Alpine test site are presented in this paper.
1. Introduction

Europe has a great history of mining activity that dates back to prehistoric times. The land surface and sub-surface provides the physical infrastructure for all human activities. The European mining and extractive industry contributes about 7% of the gross domestic product of the EU from this resource and feeds essential raw materials to all other EU industries at local, regional and EU-wide scales. However the European mining industry is facing increasing environmental pressure and regulatory controls. Whole regions are affected and in some cases devastated by the results of mining activities, and also by the more recent industrialised phase of mine development.

Industrialists and decision-makers need innovative and cost-effective tools for environmental data acquisition and processing that provide the sound basis for a dialogue ensuring the sustainable economic development of the mineral industry.

2. Objectives

The strategic objectives of this project are to develop the components of a possible future decision making tool for use in environmental planning, and to disseminate knowledge and generate awareness of the role that can be played by Earth Observation data in this process.

To reach these objectives eleven European organizations collaborate in monitoring and assessing environmental impairments caused by mining activity in order to facilitate targeted reclamation measures. MINEO brings together seven European Geological Surveys (BRGM-France, GTK-Finland, GBA-Austria, BGS-United Kingdom, GEUS-Denmark, BGR-Germany, IGM-Portugal), members of EuroGeoSurveys, the association of the geological surveys from the European Union, mining companies, an environmental institute (NERI) and the EC Joint Research Centre, Ispra.

MINEO aims at developing advanced methods for the extraction of information and knowledge from Earth Observation data, which will be required in the future in order to provide EC and users (industry, decision-makers) with new and regularly updated thematic layers for environmental database related to mining areas. MINEO intends to develop operational tools for preparing and updating these layers.

The methodological developments over six different test areas in various environmental context are aiming at:

- A spectral identification of contaminated areas (reference spectral libraries)
- Developing specific image processing for discrimination of contaminated areas (hyperspectral image processing algorithms)
- A GIS modelling of pollutant dissemination, impact assessments and environmental monitoring (models)

The Development of generic tools at European scale comprehend...
Generic hyperspectral image processing procedures for mining environments in diverse European contexts

Generic models of pollution migration and risk mapping, based on Earth observation and integration into GIS

the simulation of future hyperspectral satellite data

The development of the key components of the decision making tools and methods to exploit these data will later facilitate their use in sustainable information systems. These will be used to locate and monitor environmental risks related to mining sites and aid the decision processes.

Such tools will give a sound basis for effective environmental management through a dialogue between industrialists and decision-makers. This will promote sustainable development of the mineral industry, which faces increasing environmental pressure and regulatory controls. Environmental Impact Assessments (EIA) and Environmental Management Plans (EMP) indeed need regularly updated environmental database layers related to mining environments.


Choosing innovative Earth Observation techniques like new hyperspectral sensors the MINEO team was convinced to achieve their high aims. Hyperspectral imaging sensors produce data that can characterise the chemical and/or mineralogical composition of the imaged ground surface. The primary advantages of this future space-borne imaging technique are the reduction in hazardous, time-consuming and expensive field sampling methods and their capability to gather repeat data and so monitor mining pollution.

To undertake the envisaged methodological developments, six mining areas have been selected as test sites for investigation, to reflect European climatic, geographic and socio-economic environment diversity: 5 within Europe (Finland, Austria, Germany, United Kingdom and Portugal) and one in Greenland. (Chevrel S. et al. 2001)

This six test sites have been flown at an altitude of 2000-2500m above ground level using the HyMap airborne hyperspectral imaging spectroradiometer operated by HyVista Corporation (126 bands in the 450 - 2500 nanometers range) during summer 2000. Simultaneous ground radiometric measurements have been carried out for further calibration of the airborne data as well as for generation of European-scale spectral libraries of contaminated areas. Supplementary many relevant environmental data have been acquired during summer 2000 over the six test sites.

MINEO participants have carried out methodological developments in image processing to map contamination related to mining over the individual test sites.

Among the most significant recent breakthroughs in remote sensing has been the development of hyperspectral sensors and the software to analyse the resulting image data. Remote hyperspectral instruments, such as HyMap, deliver image data with ra-
diance values for a large number of wavelengths. Being contiguous, these bands define a continuous spectrum of sufficient detail to identify and differentiate the spectral signatures of many earth surface materials in a way that is often not possible with imaging systems, such as the Landsat series of satellites, that deliver a relatively small number of bands (termed multispectral imagery).

Using hyperspectral imagery it is possible to map the abundance of minerals (in areas with little vegetation cover) and it may also be possible to distinguish the species of vegetation cover.

Imaging spectrometers or "hyperspectral sensors" are remote sensing instruments that combine the spatial presentation of an imaging sensor with the analytical capabilities of a spectrometer. They may have up to several hundred narrow spectral bands with spectral resolution on the order of 10 nm or narrower (Goetz et al., 1985). Imaging Spectrometers produce a complete spectrum for every pixel of the image (Figure 1). The end result of the high spectral resolution of imaging spectrometers is that we can identify materials, where with broad-band sensors like Landsat Thematic Mapper ™ we could previously only discriminate between materials.

Fig. 1: The imaging spectrometer concept, hundreds of spectral images, thousands to millions of individual spectra (from Vane, 1985)

Fig. 2: HyMap hyperspectral scanner

4. Alpine Test site – Steirischer Erzberg

The Austrian test site “Steirischer Erzberg” represents a mining site in an alpine environment. (Belocky R.,Grösel K. 2001) The “Steirischer Erzberg” iron ore deposit is located 60 km NNW of the city of Graz in the province of Styria. Mining took place since Roman time. In the 16th century underground mining started, which was closed down in 1986. Since the 18th century open pit mining activities increased, which are still underway. Since the beginning of mining activity about 230 million t of iron ore have been mined at the Erzberg; 200 million t in this century. There are still 140 million t of recoverable and another 95 million t of geological reserves left.
The Erzberg is the biggest iron ore open pit mine in central Europe. Mining activities encompass the whole mountain, which rises about 700 m above the bottom of the valley up to 1465 m above sea level and covers an area of about 6.5 km². Mining is done in about 30 levels with an height of 24 m. The annual production is approximately 1.5 million tons of iron ore with an iron content of 21%. Main ore minerals are siderite, ankerite and ferrous dolomite. Accessory minerals are pyrite, arsenopyrite, chalcopyrite, tetraedrite and cinnabar.

4.1 Specific problems at the Alpine test site

4.1.1 Landscape degradation

Alpine environment is extremely sensitive regarding the interference in the natural ecosystem. Open pits, mining dumps, and tailing dams are a severe degradation of the environment. Due to the specific climatic and topographic conditions in an alpine environment nature's self-healing capabilities are considerably reduced. As in this area the economy relies on tourism to a considerable extent, human support is needed to minimise the negative effects of mining activities and to speed up the process of mining site re-naturation.

4.1.2 Landslides - dump slope stability

Not stabilised mining dumps are a potential thread because of the possibility of dump slides, endangering people, infrastructure, and the environment. Dump stability depends on many factors, e.g. type of material, grain or block size, slope angle, thickness, water content and type of cover (uncovered material, different types of vegetation). Mining dumps can be stabilised by means of landscaping and reforestation, thus regulating the water balance within the tailings.

4.1.3 Contamination

Because of the relatively pure carbonatic iron ore mined at Erzberg, direct contamination by toxic material is not a major problem in this case. However in general mining dumps are a potential thread to the environment because of leaching of toxic elements by precipitation, or dust blow-out from the tailings. These effects can be reduced by targeted remediation activities, reforestation being an effective method to inhibit excessive percolation of dumps by precipitation. Therefore methods for environmental monitoring developed at Erzberg test site will be applicable also to mining sites with serious contamination problems.
5. Processing of HyMap data for land cover mapping for site remediation assessment and monitoring.

Due to the specific requirements for site remediation assessment and monitoring at the Erzberg mine hyperspectral data interpretation for land cover mapping was performed to:

- identify relevant lithological units
- assess iron carbonate weathering intensity
- monitor (re)-vegetation status

These goals were pursued by the application of dedicated hyperspectral image data processing techniques.

5.1 Lithological mapping

The composition of the ground is a key parameter for revegetation planning purposes. To map the different lithologies a Spectral Angle Mapper (SAM) classification technique was used. This technique is relatively insensitive to illumination effects, an important issue considering Alpine topography. Figure 3 shows the result of the SAM classification.

![Fig 3: Remotely identified lithology employing SAM classification technique](image-url)
5.2 Iron carbonate weathering intensity mapping

Iron carbonate weathering is another main parameter for site remediation at the Alpine test site. During weathering of iron carbonates oxidic coatings are formed covering the rock components and inhibiting further rock decomposition and pedogenetic processes. Therefore an algorithm was developed to map the intensity of iron carbonate weathering.

![Fig. 4: Remotely identified iron carbonate weathering intensities](image)

5.3 Vegetation mapping

Standard image processing uses NDVI (normalised difference vegetation index) for vegetation mapping. Under the specific conditions of the mining environment NDVI gave erroneous results as strongly weathered iron carbonates are falsely mapped as vegetation. Therefore a suitable vegetation index was developed using the high spectral resolution of the hyperspectral data at the “red edge” between 631 and 799 nm.
6. Conclusions

Dedicated algorithms for the interpretation of hyperspectral remote sensing data are excellent tools to derive key parameters essential for mining site remediation planning and monitoring in an Alpine environment. These parameters comprise the general lithological/mineralogical composition of the ground, specific information on the weathering intensity of iron carbonates, as well as vegetation distribution and intensity.

The integration of remotely derived data with ground control information on geology, mineralogy, geochemistry, vegetation, and digital elevation data provides a comprehensive GIS based database for mining reclamation activities.

Bibliography


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