

HYPERSENSPECTRAL AIRBORNE IMAGERY FOR MAPPING MINING-RELATED
CONTAMINATED AREAS IN VARIOUS EUROPEAN ENVIRONMENTS – FIRST RESULTS OF
THE MINEO PROJECT*

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ABSTRACT

MINEO is a European Research and Technological Development project which aims at developing tools and methods for assessing and monitoring the environmental impact of mining activities by means of combined Earth Observation and other relevant environmental data set. MINEO is designed to improve the already proven hyperspectral imagery capabilities in mineral mapping for use in the mapping of mining-related contaminated areas in European vegetated environments. The final objective is to prepare tools for the regular updating of environmental databases from very high-resolution future spaceborne missions.

Six mining areas in Europe have been chosen to carry out the methodological developments. They have been flown at an altitude of 2000-2500 m above ground level during summer 2000, using the HyMap hyperspectral imaging spectroradiometer operated by HyVista Corporation. Simultaneous ground radiometric measurements have been carried out for further radiometric calibration of the airborne data as well as for the generation of European-scale spectral libraries of contaminated areas.

The paper presents the preliminary results of the project's on-going developments in mining-related contamination mapping.

1. OBJECTIVES OF MINEO

MINEO is a shared-cost RTD action co-financed by the Fifth Framework Programme of the European Union, Information Society Technologies.

The responsible management of Earth's environment is one of today's most pressing concerns. Sound environmental management of mining activities avoids high remediation costs, which frequently drain public funds. Understanding and monitoring pollution processes in mining areas is therefore of concern

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to a very wide user community, including central government bodies or agencies, local authorities, industry, environmental groups and individual citizens.

Environmental Impact Assessments (EIA) and Environmental Management Plans (EMP) can take advantage of regularly updated environmental database layers related to mining environments. Innovative Earth Observation (EO) techniques being developed by a team from seven European Geological Surveys, members of EuroGeoSurveys, and their partners can meet this demand. Hyperspectral imaging sensors produce data that can characterise the chemical and/or mineralogical composition of the imaged ground surface. The primary advantages of this imaging technique are the reduction in conventional, time-consuming and expensive field sampling methods and their capability to gather repeat data and so monitor mining pollution.

Earth Observation data, when integrated into Geographic Information Systems and combined with other data relevant to environmental concerns, have been proven to be valuable in the environmental impact assessment of mining, both at local and regional scales. In particular, they can be used in the production of pollution-risk maps around mining areas (Dalton *et al.*, 2000; Swayze *et al.*, 2000; Chevrel & Coetzee, 2000; Coetzee & Chevrel, 1997). MINEO therefore intends to develop the contribution of various Earth Observation techniques further. The most advanced current airborne hyperspectral sensors are used to detect mine-waste pollution and soil/aquifer contamination. In particular, their capabilities in detecting and discriminating major pollutants are under assessment and validation during field campaigns.

Regular acquisition of such high-resolution, remotely sensed geographic information will help the Community to set up a realistic, sustainable and coherent environmental management and monitoring strategy at the European scale.

The objectives of MINEO are:

- To develop 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 and to develop operational tools for preparing and updating these layers;
- To develop the key components of the decision making tools and methods to exploit these data and facilitate their use in sustainable information systems, 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, ensuring sustainable development of the mineral industry, which faces increasing environmental pressure and regulatory controls.

To undertake the envisaged developments, six mining areas (see Fig. 1), five within Europe (Portugal, United Kingdom, Germany, Austria, and Finland) and one in Greenland have been selected for investigation, to reflect European climatic, geographic and socio-economic environment diversity.

2. THE HYPERSPECTRAL AIRBORNE DATA ACQUISITION CAMPAIGN

MINEO relies on the use of high quality airborne hyperspectral imaging spectrometer data. The main concern during the airborne survey was to acquire as much high quality hyperspectral image data from the six test sites as time and weather would allow. The hyperspectral data acquisition campaign took

place during summer 2000, using the HyMap sensor, operated by HyVista Corporation. Flight operation and simultaneous aerial photography acquisition have been subcontracted to Deutsches Zentrum für Luft und Raumfahrt, e. V. (DLR), using a Dornier 228 aircraft (see Fig. 2). The aircraft flew at 2500 m above ground level at a speed of 150 knots (277 km/h), enabling images at 5 m ground resolution, with a 20% overlap of the three Km swaths.

The HyMap scanner, built by Integrated Spectronics, Pty, Ltd, Australia, has four spectrometers in the interval 0.45 to 2.45 micrometers excluding the two major atmospheric water absorption windows. It images in 126 bands. The bandwidths are not constant, but vary between 15 and 18 nanometers. The scanner also has an on-board bright source calibration system, which is used to monitor the stability of the signal. The signal/noise ratio measured outside the aircraft with a sun angle of 30° and a 50% reflectance standard is more than 500/1, except near the major atmospheric water absorption bands.

3. BRIEF DESCRIPTION OF THE MINEO TEST SITES

3.1. ARCTIC ENVIRONMENT TEST SITE : MESTERSVIJ MINING AREA – GREENLAND

The mineralisation was discovered in 1948 and mined from 1956 to 1963. Mining operations influenced the drainage system and induced environmental problems related to the transport and shipping of the concentrate. Intense runoff and strong winds are the main factors for the dispersion of pollutants. Only insignificant remediation measures have been carried out since closure.

3.2. BOREAL ENVIRONMENT TEST SITE : LAHNASLAMPI TALC MINE – FINLAND

Mineral dust composed predominantly of talc and carbonates is disseminated to the surrounding environment by wind at this operating open-pit mine. Ni and As are diluted by surface waters from the ore material. Black shales with anomalous amounts of sulphides and metals can cause contamination and acidification of surface and ground waters.

3.3. ALPINE ENVIRONMENT TEST SITE : EZBERG MINE – AUSTRIA

Active mining areas exhibit fresh rock surfaces of different lithologies. Abandoned mining areas comprise weathered rocks of different types covered by vegetation of different intensity and condition. Open pits, mining dumps, and tailing dams are a severe degradation of a very sensitive environment.

3.4. CENTRAL EUROPE URBANISED ENVIRONMENT : KIRCHHELLER HEIDE COAL MINE – GERMANY

Hard coal exploitation from more than 800 m under the surface causes surface subsidence and changes in the environmental balance (e.g. groundwater level, flowing directions, and vegetation). The monitoring of the environmental balance and its changes is essential for this semi-urbanised area.

3.5. WESTERN EUROPE ENVIRONMENT: WEST CORNWALL MINING DISTRICT – UNITED KINGDOM

The UK study site is an area of abandoned tin mining in Cornwall. Mineralisation in the region occurred in several phases during emplacement of a granite intrusion. Mining began in the Bronze age, peaked in the late 19th century, with the extraction of copper, tin, and tungsten, and then declined post

War, before ceasing in the 1990's. This has left a landscape scattered with disturbed ground and abandoned mining adits. The aim of the project is to identify the minerals present at these sites, and assess their dispersion in the local environment using airborne Hyperspectral data.

3.6. SOUTHERN EUROPE ENVIRONMENT: SÃO DOMINGOS MINE – PORTUGAL

The mineralised body was cupriferous pyrite associated with Pb and Zn sulphides. Mining activity started since pre-roman and roman times, and became important again during 19th and 20th centuries until its closure in 1966. The environmental effects of exploitation include landscape degradation with the production of 7,5x10⁵ tons of scoria and open pit filled with acid waters (pH=1,7). The acid drainage from mining effluents, estimated at 2hm³/year during productive phase, affects soils and waters along several km. Chemical data also confirm contamination with high values of Pb, Cu, Zn, S, As, Fe and Sb.

4. OVERVIEW OF SOME CURRENT MINEO DEVELOPMENTS

4.1. GENERALITIES

4.1.1. Field spectrometry

Field campaigns have been organised during summer 2000 in view of i) collecting all relevant data on test site environments (baseline, pollution processes,...) and ii) taking field spectroradiometric measurements.

During flight measurements were performed for imagery calibration (black and white ground targets) and reference target measurement. Spectroradiometric measurements of various environmental targets constitute the base for a specific spectral data set to be compared to laboratory measurements and image spectra, as well as geochemistry.

4.1.2. MINEO Spectral library

One of the major MINEO outputs is the development of a dedicated spectral library of contaminated areas that reflects diverse European mining-related contaminated environments. MINEO develops, and regularly updates, its own spectral database to handle its spectral library and facilitate specific image processing for mapping contamination. Among data base facilities are the capability to retrieve:

- Spectra similar to a "suspicious" image signal and their significance in terms of contamination
- Indicative spectra corresponding to a specific environmental problem

Spectra from the database can be interactively displayed in the image processing software (ENVI)

4.1.3. Image processing and Contamination mapping

Prior to proceeding to "thematic" image processing, HyMap data have been atmospherically corrected and geocoded using DTM's derived from aerial photos acquired simultaneously with hyperspectral data.

Various attempts for image processing, using routine algorithms (Minimum Noise Fraction or MNF, linear unmixing, etc.) have already been performed. Further developments will take place during summer 2001, accompanied with new field campaigns.

4.2. SELECTED EXAMPLES

4.2.1. UK test site

The red coloration on HyMap natural colour composite of Wheal Jane reveals the high iron concentration of the acid mine water in the tailings pond (see Fig. 4a). PIMA (Portable Infrared Mineral Analyser) is used to compare ground spectra with hyperspectral data to verify remote sensing analysis. Fig. 4b shows a PIMA spectrum from Wheal Pendarves mine and the closest matching kaolinite spectrum. Detailed hyperspectral analysis has now commenced

4.2.2. Finnish test site

Extensive field spectroradiometry campaign has been undertaken over the Finnish test site area to pick up spectral signatures of various environmental features.

A spectroradiometric profile (See Fig 5c), measuring reflectance of *Picea Abies* twigs, revealed variation in reflectance with distance to the mine, due to dust. It seems that dust tends to decrease reflectance in the NIR range and increase it in the SWIR (see Fig. 5d). Subtle colour differences, visible in the form of a halo surrounding the mine on MNF-4-5-6 colour composite image (see Fig. 5b) may reflect this difference in reflectance. Further field investigations are nevertheless required for confirmation of these features during 2001.

MNF-3-4-5 colour composite image also reveals a yellow-orange area (Fig. 5a), south of the mine that corresponds to a marshy area with dead trees. The area has previously suffered from stream flooding caused by beavers: all tree are practically dead but understorey moss vegetation remains alive. The site of the beaver dam is visible at the NE tip of the flooded area.

4.2.3. Austrian test site

The aim of the study is to map the spatial distribution of different rock types and minerals present at the mining site using hyperspectral remote sensing data as a basis for targeted reclamation activities, especially in the fields of revegetation and reforestation under alpine environmental conditions.

On going interpretation of hyperspectral data is assisted by field spectroscopy employing portable spectrometers such as the PIMA (Fig. 6a and 6B). All main lithologies can be identified by their specific spectral features. Special emphasis is laid on the discrimination of carbonate rocks in respect to their different content of Ca, Mg, and Fe. Siliciclastic and metavolcanic rocks are differentiated by their specific types of phyllosilicates.



Fig. 1. Location of the Test Sites (dark squares)



Fig. 2. Dornier 228 DLR Aircraft



Fig. 3. HyMap Sensor on Board of the Aircraft



Fig. 4a : True colour HyMap Image of Wheal Jane tailings pond showing iron concentration

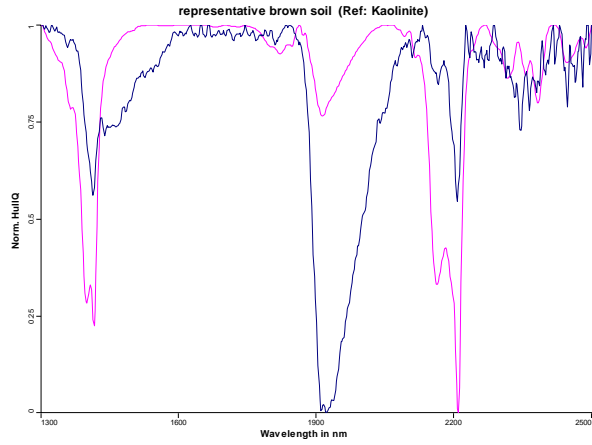


Fig. 4b Example PIMA spectrum from Wheal Pendarves mine and closest matching kaolinite spectrum

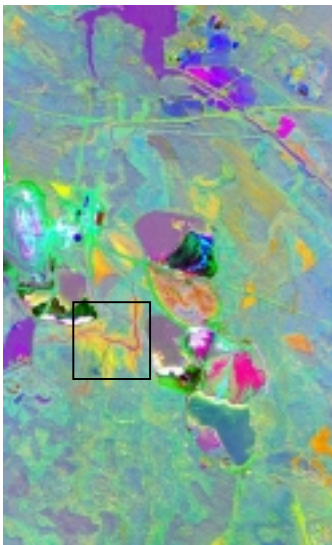
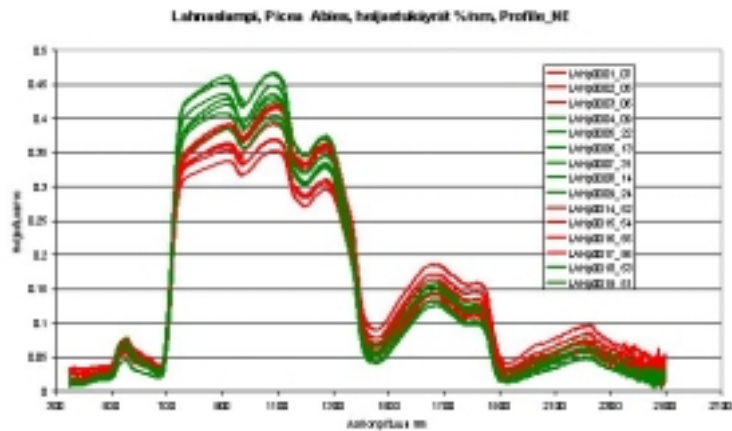
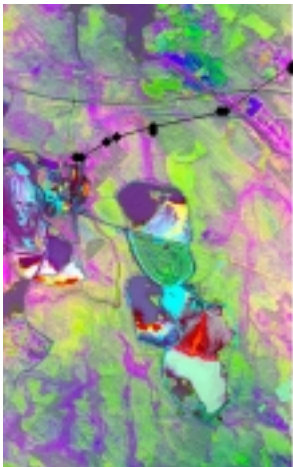
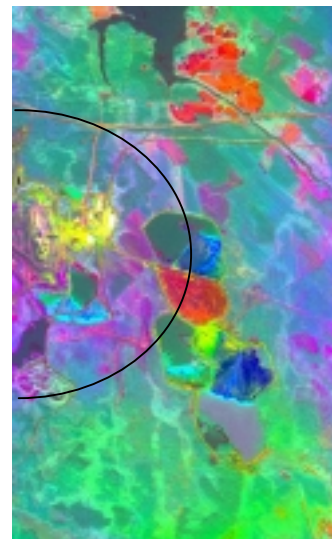
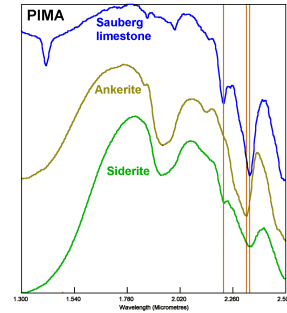
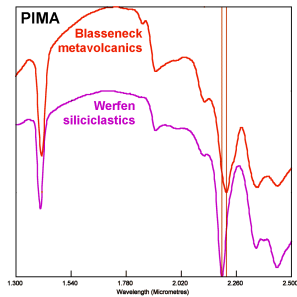
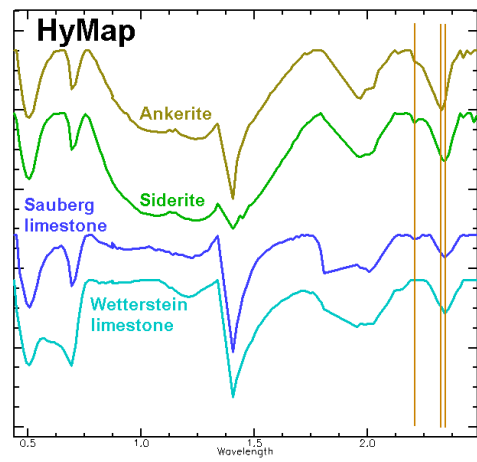
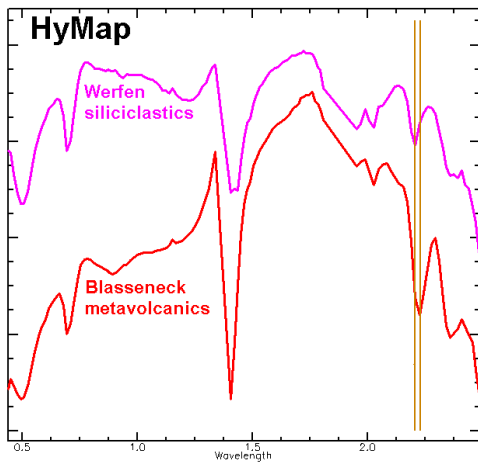


Fig. 5a (left) : MNF-3-4-5 colour composite image of the Lahnaslampi mine area outlining dead tree zone south and south-east of a tailing pond (within the black square).

Fig. 5b (right) : MNF-4-5-6 image highlighting a subtle halo around the mine area (dark circle)

Fig. 5c and 5d (bottom) : spectral profile of *Picea Abies* twigs with distance to the mine (red spectra = distance to the mine less than 1Km)





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