MINEO TWO YEARS LATER DID THE PROJECT IMPULSE A NEW ERA IN IMAGING SPECTROSCOPY APPLIED TO MINING ENVIRONMENTS?

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ABSTRACT

MINEO was a shared-cost action contracted in late 1999 with the Directorate General for Information Society Technology of the EU in the framework of the 5th European Research and Technological Development programme. MINEO was the first “hyperspectral project” carried out at European scale. It gathered seven Geological Surveys members of EuroGeoSurveys[1], two mining companies, the Joint Research Centre from the EU and the Danish Environmental Research Institute. MINEO aimed 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 sets. MINEO was in particular designed to improve the hyperspectral imagery capabilities in mineral mapping in view of their use in the mapping of mining-related contaminated areas in European vegetated environments. The final objective was to develop the necessary tools for a further regular updating of environmental databases from future very high-resolution airborne and spaceborne missions.

Two years after the completion of the project, and after a review of the major project outcomes and lessons learnt, the 4th Workshop on Imaging Spectroscopy is a good opportunity to make a statement on the contribution of MINEO developments and skills to mining-related environmental studies in Europe and elsewhere. The benefit of imaging spectroscopy to the regulatory framework, in particular European Directives, and ways to foster its appropriation by regulators is discussed.

INTRODUCTION

MINEO was initially designed to demonstrate the capabilities of imaging spectroscopy in identifying, characterising and mapping mining-related contamination or impacts in European densely vegetated environments, keeping in mind the requirements for future inventories and/or monitoring of these impacts at local, regional to national or European scale.

MINEO voluntarily had chosen to diversify the mining and climatic environments for its test sites areas, in view of reflecting the European diversity and hence meet most of Europe’s climatic and mining environments and develop relevant tools and methods. Europe has a very wide diversity of environments, ranging from semi-arid in the south to boreal in the north, and even arctic when including Greenland. Europe mining activities also encompass a variety of extracted materials and mine types, each associated to specific relevant environmental concerns.

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[1] The association of the Geological Surveys of the European Union

The choice of the test sites reflected this diversity with followings:

- Lead – Zinc mine in arctic environment (Mestersvig, Greenland), with underground and surface mining operations;
- Open pit talc mine in boreal environment (Lanhaslampi, Finland)
- Siderite mine in Alpine environment (Steirische Erzberg, Austria)
- Underground coal mine in central Europe urbanised environment (Kirscheller Heide, Ruhr area, Germany)
- Copper - tin abandoned mining district in western European environment (Cornwall, UK)
- Metal sulphide open pit mine of the Iberian Belt in southern Europe environment (Sao Domingos, Portugal)

MINEO MAJOR OUTPUTS

Very encouraging results have been obtained in the contribution of airborne imaging spectroscopy to the study and monitoring of mining environments, despite the very challenging but problematic abundance of vegetation characterising the European environments. Hyperspectral imagery has proven invaluable capabilities in mapping mining-related contamination and/or impacts. Promising results have been obtained in combining those resulting maps with other relevant information under GIS for modelling contamination, pollution risk, site rehabilitation or change detection.

Scientific results

In Greenland, imaging spectroscopy enabled the mapping of arctic vegetation contaminated by windblown tailings, and the downstream contamination of the drainage system by sphalerite bearing tailings.

In Finland, imaging spectroscopy has been used to map dust and seepage contamination related to the talc mine over different boreal forest species. It has revealed that the influence of mining seems to have had more effect on reflectance, that is the health of mature spruce stands than that of mature pine and birch stands, in the vicinity of the mine.

In Austria, different outcropping lithologies relevant to site re-vegetation potential have been mapped from hyperspectral imagery. In particular the mapping of iron-carbonate weathering intensity and its relationship with vegetation health in re-vegetation process has been established. This led to the development of a model that includes parameters to support mining re-vegetation techniques. This model gives a rapid overview of re-vegetation conditions and costs from information about the existing vegetation status (vegetation cover, vegetation types), the terrain (relief, elevation differences), soil and moisture conditions and the lithological situation. All this information, extracted from hyperspectral imagery processing is combined, ranked, and recalculated into a single layer to assess re-vegetation feasibility and probability of success

Imaging spectroscopy data has been used over the German test site to estimate vegetation vitality and detect "vegetation stress" caused at surface by mining operations, in particular related to subsidence and water logging. Maps of the reaction of vegetation to these changes have been generated. These maps contain the development and distribution of vegetation stress and the alteration of biotope types in time series. Such maps are intended for use in environmental monitoring and landscape development management.

In the UK, despite the very high moisture content of the soil and the densely vegetated environmental conditions, imaging spectroscopy made possible the mapping of the extension of different iron oxides at Wheal Jane tin mine and their contamination plume downstream to the river estuary.

The most important contribution from hyperspectral data at Sao Domingos mine in Portugal has been to detect evidences of superficial Acid Mine Drainage (AMD) and related pollutants and map their extension. Mapping waste mining materials from soil and rock reflectance spectra collated in the field and mapping AMD minerals using the USGS mineral spectral library both show a good correlation of mineral and waste extension with the map of different type of mine wastes drawn from field reconnaissance.

Perspectives opened by MINEO

The MINEO project and other have shown that airborne imaging spectrometry data offer effective methods for remote identification and characterisation of materials in mining environments using dedicated digital image processing. Airborne imaging spectrometer data, in particular those from the HyMap sensor, have high spectral and spatial resolution and are therefore useful in environmental studies. Some of the tools developed present a 'generic' enough character to be used not only locally, but also in many other mining areas in Europe.

The MINEO project has developed and validated methods that can, alone or in combination with other remote-sensing and conventional field methods, be used in inventorying those 'time bombs' and their environmental impact and to monitor their evolution over time. The Aznalcollar and Baïa Mare accidents are among the type of events where MINEO and equivalent methods could have been of use. Specific environmental site studies and monitoring are also relevant to these techniques and can help in optimising the efficiency and cost of environmental management.

Despite based only on six test sites, this large diversity of results and approaches show that imaging spectroscopy can bring an invaluable contribution to very diverse environmental concerns, in a large variety of mining environments and in different morpho-climatic contexts. This opens large encouraging perspectives, in particular in regular mapping and monitoring of large parts of the territories to regularly update thematic layers for environmental database related to mining areas, despite it is clear that this very innovative method has to be matured before reaching a real operational status.

MINEO TWO YEARS LATER

Potentials and actions for a MINEO follow up

The successful completion of MINEO and the perspectives opened by this demonstrative project gave rise to a dynamics of success that has, in a first time, led to the submission of a FP6 Expression of Interest for an integrated project, the so-called MINEO_II project.

In the perspective of the evolution of the European policy context, the MINEO_II concept aimed at the development of services and methods to inventory, identify, characterise, map and model contaminated lands and associated risks (mining areas, industrial areas, landfills, derelict lands) based the integration of spaceborne, airborne and ground techniques. The concept includes two major components :

- Development of EO-, GIS- and Internet-based integrated services in the field of environmental monitoring and management, aiming at integrating various geophysical and Earth Observation airborne or spaceborne methods, ground techniques and existing databases for assessing and monitoring contaminated lands in an environmental risk-management perspective
- Research and technological development in the fields of sensors and processing of remote-sensing methods, including geophysics, hyperspectral imagery and thermal-infrared imaging spectroscopy.

MINEO_II unfortunately never went further than an Expression of Interest, none of the earliest FP6 calls being likely to fit for a successful project submission, despite a strong demand and initiatives to monitor soil contamination in European policies: 6th Environmental Action Programme, forthcoming Mining Waste Directive, Soil Thematic Strategy, etc.

An attempt to implement a EUREKA funded project to develop environmental services based on hyperspectral remote sensing failed due to the difficulty to assess the potential "commercial" market and relevant Return on Investment.

Current situation

Despite many efforts from the MINEO partners and a number of other organisations, there still are few projects in European countries dealing with imaging spectroscopy applied to mining or industrial related environmental concerns. Moreover, these projects are generally research oriented and cannot hence be considered as real-case operational application of imaging spectroscopy to contribute solving environmental problems.

Apart from DSK activities, few MINEO follow-up was really implemented in the MINEO Consortium organisations once the project completed.

Favourable factors

The MINEO_II concept received, and still receives, a large consensus in the relevant scientific community and has been initially joined by about 30 participants from over the world ready to participate in such a project.

Furthermore, since the completion of MINEO and the submission of the MINEO_II EoI, the MINEO partners have been contacted by several tens of scientific organisations, which have expressed their interest in the project development and their motivation to “join the team”. That includes sensor developers, UAV developers, remote-sensing organisations, environmentalists and geological surveys. Furthermore, they are frequently contacted to give presentations, attending conferences or writing short articles.

These encouraging contacts prove the international recognition of a valuable concept. Moreover, MINEO is now included in the GMES-relevant FP5 projects.

The forthcoming European Directive on Mine Waste opens new challenging perspectives for the application of the concept initiated in MINEO and proposed in MINEO_II. Application of the article 19 of the Directive requires EU countries to proceed to inventories of their mine waste as well as to rehabilitate sites at risk.

Eventually, the forthcoming European airborne sensors ARES and APEX should boost the development of airborne campaigns in Europe. These sensors presents characteristics of particular relevance for environmental studies and ARES, with its TIR bands, should impulse a new field of activity in the application of TIR spectroscopy to mining-related mineral detection like silicates, a major component of many tailings material. The availability of high performance sensors based in Europe will be a favourable factor, could lower the price for data acquisition and be a major contribution in case of need for emergency response to accidental disasters like tailings spills.

Disadvantaging situation

During the past decade, MINEO and several projects in other countries like USA and Australia have demonstrated the invaluable contribution of imaging spectroscopy in mapping mining-related impact and/or contamination. The contribution of Earth Observation in mining-related risk assessment and ranking has been demonstrated as well.

One could hence reasonably hope these successful demonstrative applications would have boost the use of IS in mining environment studies and that IS could no more be ignored for such applications. These successful stories however not yet gave emergence of “real case” application, neither in terms of monitoring sites nor in terms of studies at catchment or mining district scale.

This relative “lack of success” gives rise to several questions that have to be analysed.

Causes are probably multiple, cost of data acquisition and processing being the most frequently put forward.

Costs: As said above, the cost of data acquisition seems to be major sticking factor and most of current projects exist because data acquisition has been subsidised. Even if the cost of data acquisition and processing is undoubtedly higher than for conventional remote sensing methods, it has nevertheless to be analysed in terms of cost/benefit ratio. It is proven that monitoring programme can be considerably optimised and subsequent cost minimised by an integrated hyperspectral remote sensing study. MINEO has also demonstrated that rehabilitation programme can take benefit of imaging spectroscopy and inherent cost reduced.

Lack of education and black box feeling: Another reason lies in the lack of information of the end users on the possibilities of the technique and a "black-box" feeling that could induce fear or reluctance in using it. Indeed, users need integrated ready-for-use products or studies more than a demonstration of the remote sensing capabilities. Scientists now need to adapt themselves to the users and better explain what the contribution of remote sensing is in an integrated environmental management approach.

Maturation of the technique: automatic detection of relevant information (minerals, rocks, vegetation stress, etc…) and its repetitiveness can be considered as key points to convince end users that they can rely on a robust tool. This particular point demands further RTD.

Market readiness: The readiness of the potential market has to be better appreciated. The EU Directive on Mining Waste and its application at national level is likely to open large institutional market opportunities, despite policy makers and decision makers have to be convinced of the benefit of using IS in inventories, monitoring and rehabilitation processes. On the other hand, recent market studies tend to prove that most of the mining companies are satisfied with conventional site monitoring techniques with minimised relevant costs and appear reluctant to use new technology they feel expensive and uncertain.

PROPOSALS

Scientist are convinced they have the right tool in their hands to meet the forthcoming environmental European regulation challenge, but today probably only scientists are…It is hence necessary to deploy strong efforts to convince the right decision makers at the right time (i.e. now!).

To this end and to be able to meet on time the environmental regulation challenges, it is here proposed to built up a network bridging the gap between scientist and end users, with the aim to:

- be prepared to go beyond RTD and propose real case studies
- establish a partnership network, including SMEs : sensor developers, flight operators, image and GIS processing, Earth scientists, environmentalists, mining engineers, etc
- lobby whoever is to be lobbied…:EU DGs, national to local authorities, Chamber of Mines, Mining associations, Development Banks (WB…), space agencies
- actively participate in all working groups of relevant policy
- participate in "non remote sensing" conferences and publish in "non remote sensing" reviews
- review all project opportunities
- better inform and be better informed

CONCLUSIONS

The MINEO project has been recognised as a valuable concept and gave impulse to an unquestionable scientific interest. It has been a real impetus that appealed several newcomers in the domain of imaging spectroscopy applied to mining environments. GMES, the forthcoming European Directive on Mining Waste and the arrival of new high-performance hyperspectral sensors based in Europe open challenging opportunities to foster the use of imaging spectroscopy in environmental studies.

However, the turning point between scientific RTD and operational status is still to be done, should the scientific community be able to face scientific and "commercial" obstacles and better understand and answer institutional and private stakeholders needs. This includes cost of data acquisition and processing, maturity and automation of the technique, integrated approaches and lobbying.

It is hence proposed to establish a network with the objective of fostering the development of IS applied to mining and industrial environments, by better opening the imaging spectroscopy community to the end-users. Such a network will aim to organise the community to unlock the situation and go beyond RTD whilst stimulating better targeted RDT, to unit our strengths and skills to enhance the value of our concept

Eventually, the lack of ambitious projects at national or European scale, like the US EPA Superfund programme for cleaning up the nation's hazardous waste sites, disadvantages a sustainable growth of this invaluable technique.

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