Coordinating and integRating state-of-the-art Earth Observation Activities in the regions of North Africa, Middle East, and Balkans and Developing Links with GEO related initiatives towards GEOSS

D4.7 – Pilot activity report – Access to Raw Materials

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Prepared by	Maria Przyłucka[1,3], Eleftheria Poyiadji[1,2], Marianthi Stefouli[1,2], Kiki Hatzilazaridou[1,2], Zbigniew Kowalski[1,3], Stanisław Wołkowicz[1,3], Albin Zdanowski[1,3], Isabel Pino[1], Christodoulos Hadjigeorgiou[1,4], Özgür Acir[5], Hayati Koyuncu[6] [1] EuroGeoSurveys, the Geological Surveys of Europe [2] Institute of Geology and Mineral Exploration, Greece [3] Polish Geological Institute – National Research Institute, Poland [4] Cyprus Geological Survey, Cyprus [5] JADE - Association of Geological Researches, Turkey [6] JeoDijital Bilisim Teknoloji Madencilik, Turkey			
Quality Assurance	Dr. Charalampos Kontoes, Lefteris Mamais, Alexia Tsouni			
Contact Person	Dr Charalampos (Haris) Kontoes	Project Coordinator		
	Metaxa & Vas. Pavlou Str. • 152 36 Penteli, Greece			
	Email: kontoes@noa.gr	Phone: +30-2108109113	Fax: +30-2106138343	

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Executive Summary

The objective of this deliverable is to report on successes and failures, weaknesses identification, inhibitors, improvement opportunities and achieved tangible outcomes from the implementation of the “access to raw materials” specific tasks.

The aim of the pilot was to define the roadmap that facilitates the access and exploitation of mineral resources in extensively under-explored areas, thus creating well sustained businesses, in compliance with widely recognized environmental protection principles.

To achieve this goal, pilot sites (mining or post-mining areas) were chosen as feasibility studies. For this reason, a thorough communication with stakeholders and end users in the RoI was elaborated in order to identify areas facing problems related for example to:

- long term monitoring of ground deformation during or after mining activities,
- mapping of waste materials left over in abandoned mines,
- development of an appropriate protocol for the evaluation of the environmental impact, together with feasibility assessment of extractive or mining waste potential to become exploitable secondary resources.

To reach concrete mining sites, all identified geology and raw materials related institution in the RoI were asked to fulfil the short questionnaire, which aim at defining potential pilot sites. From the 7 proposals, 4 were chosen for further feasibility studies as a representation of most interesting mining and post-mining areas from the point of view applicability of the EO methods. The elaborated and presented, in this deliverable, methodologies are the main goal of the pilot.

The elaborated EO methodologies are useful for better management of the mining and post-mining areas and reduce their impact on the surrounding areas. It is expected that the methodologies elaborated on the examples pilot sites will have a universal character and could be applied for other RoI as well.

In the future the proposed pilot studies should be realised as operative projects in order to verify usability and effectiveness of EO methods on these particular areas.

Project Information

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Project Beneficiaries:

ID	Participant Organisation Name	Country	Logo
1	National Observatory of Athens (NOA) - **Coordinator**	Greece	
2	Interbalkan Environment Center (IBEC)	Greece	
3	Center for Environment and development for the Arab Region and Europe (CEDARE)	Egypt	
4	Research and Studies Telecommunications Centre (CERT)	Tunisia	
5	Tel Aviv University (TAU)	Israel	
6	Cyprus University of Technology (CUT)	Cyprus	
7	TUBITAK UZAY Space Technologies Research Institute (UZAY)	Turkey	
8	Space research and technology institute (SRTI)	Bulgaria	
9	National Institute of R&D for Optoelectronics (INOE)	Romania	
10	University of Ss Cyril and Methodius (USCM)	FYROM	
11	Institute for Nature Conservation in Albania (INCA)	Albania	
12	Institute of Physics Belgrade (IPB)	Serbia	
13	CIMA Research Foundation (CIMA)	Italy	
14	Academy of Athens (AOA)	Greece	
15	INOSENS (INS)	Serbia	
16	European Association of Remote Sensing Companies (EARSC)	EU	
17	EURISY	EU	
18	EuroGeoSurveys (EGS)	EU	
19	World Radiation Center (PMOD/WRC)*	Switzerland	

*Note: Switzerland is not requesting financial contribution from the EC

Contents

Acronyms and Abbreviations

Acronym	Description
AVIRIS	Airborne Visible / Infrared Imaging Spectrometer
DTM	Digital Elevation Model
EARSC	European Association of Remote Sensing Companies
EC	European Commission
EGS	EuroGeoSurveys
EO	Earth Observation
ERS	European Remote Sensing satellite
ESA	European Space Agency
ETM+	Enhanced Thematic Mapper Plus
EU	European Union
GA	Grant Agreement
GEO	Group on Earth Observation
GEOSS	Global Earth Observation System of Systems
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
InSAR	Satellite Radar Interferometry
LIDAR	Light Detection and Ranging
MSS	Multispectral Scanner
NASA	National Aeronautics and Space Administration
NOA	National Observatory of Athens
OAGS	Organisation of African Geological Surveys
PC	Principal Component
PCA	Principal Component Analysis
RGB	Red Green Blue satellite image composition
SAR	Synthetic Aperture Radar
SRTM	Shuttle Radar Topography Mission
TM	Thematic Mapper
USGS	United States Geological Survey
WP	Work Package

List of Tables

List of Figures

Introduction to Access to Raw Material pilot

The potential of minerals exploitation and mining activity in the RoI, and their corresponding socio-economic benefits is high. More than 30% of the world's global mineral reserves are found in Africa, yet less than 5% of the total global ore deposits exploration and minerals extraction expenditures are invested. The potential for a productive and sustainable mining industry across Balkans, Middle East and Africa remains challenging and highly perspective. Reports by leading global consultants suggest that private-public-investments should be actively encouraged and sought to meet the demands for developing appropriate exploitation processes. The countries, as part of the quest to diversify and capitalise upon their minerals, face the need to establish modern, open and transparent regulatory frameworks and concerted actions for best practices, maximising the environmental, societal and economic benefits. The rationalised exploitation of minerals through a coordinated and integrated approach with clear awareness of raised environmental treaties and society needs, facilitates resource efficiency, and supports critical environmental, industrial, and business development sectors.

At the same time EO monitoring methods are more wildly use all over the world for many different applications, including raw material, and geology mapping. It seems clear that any future operational system related to natural resource management will depend on a combination of spacecraft, aircraft, and ground systems. These modes are essentially complementary for both technical and economic reasons. The major impact of EO application is already seen in the economic sectors of life on earth, including mineral exploration, agricultural yield prediction, rangeland management, water resource management, cartography, land-use planning and environmental monitoring. Government decision makers as well as privet-sector institutions, e.g. exploration companies, are pursuing this course actively on their own. Results to date indicate a number of successful applications or potential applications, including, specifically, mineral exploration. The remotely sensed data must be, however, transformed into information in a format useful for decision making by resource managers related to the mineral exploration process, restoration process or reducing the environmental impact. The ARM pilot provides a comprehensive review of the status of remote-sensing applications for mineral exploration, with emphasis on the contributions of satellite-based Copernicus data.

The extensively under-explored areas in RoI expressed the need for requirements to facilitate the access and exploitation of mineral resources for creating well sustained businesses, in compliance with widely recognised environmental protection principles. Therefore, the pilots were chosen with the aim to define the roadmap for long-term monitoring, mapping, and management of mineral deposits, also assessing the ground changes and site degradation relating to mineral exploitation.

One of the major outstanding environmental problems related to mining is that of abandoned mine sites, a legacy of centuries old practices, of inadequate, insufficient or non-existent mine closure plans. The potential costs of rehabilitation, the lack of clearly assigned or assumed responsibility, the absence of criteria and standards of rehabilitation as well as other factors have delayed action by all parties – industry, governments and communities. Yet, land degradation from old mine operations is well known in almost all countries. While derelict sites are extensively referred in the literature, there have been few systematic surveys to quantify how many sites need attention. There has been even less work to quantify the nature of associated problems so as to prioritize remediation efforts. The impact of mining sites is significant concerning environmental and safety problems including: altered landscape; unused pits and shafts; land no longer useable due to loss of soil, pH, or slope of land; abandoned tailings dumps and dams; changes in groundwater regime; contaminated soils; subsidence; and changes in vegetation. Results of such impacts include: loss of productive land; loss or degradation of groundwater; pollution of surface water by sediment or salts; changes in river regimes; risks of falls into shafts and pits; and landslides. The resulted delineated waste materials areas advance the knowledge on the critical hazardous areas for remediation purposes. The proposed roadmap promotes specifications and methodologies for engaging future operations fitted to raw materials demand, minimising the environmental footprint, and improving the evaluation of the sustainability and management of the post-mining areas.

Another major problem in the RoI, which was highlighted by UEPG (the European Aggregates Association) particularly for countries in the Balkan region, during the implementation of two EU co-funded projects, SARMa and SNAP-SEE is the illegal aggregates' quarrying activities. The problem is faced even by countries that have related extensive legislative framework for Quarrying (Greece). Illegal quarrying is related to severe economic, social and environmental impacts affecting not only the restricted area where such activities take place, but also wider areas. Regarding the monitoring of illegal quarrying activities and according to the suggestions of the Greek pilot study end-user (i.e the Ministry of Environment and Energy) there are three different types of activity that need to be surveyed: (a) Exploitation of 'quarry minerals' in quarry sites that own valid permits; (b) Potential illegal activities that are mostly taking place in old/abandoned/without an active permit quarries, and (c) Occasional exploitation activity from unpermitted sites. The objective of the feasibility study will be to support authorities in efforts for the mitigation of illegal quarrying activities by developing a Monitoring System (Tool) with the use of EO data. This Tool may be used to track any detectable potential changes of surface morphology, land use, etc. related with such activities. The methodology to be developed could be applied for the Monitoring of Illegal Quarrying Activities in any country in the Region of Interest, provided the cooperation of relevant National / Local authorities.

The third raised problem in the ROI concerns increasing access to raw materials and the support of mineral exploration management as well as waste materials analysis.

This applies to areas that have been operating for a long time, where significant environmental footprint has been left after intensive exploitation, areas that are not well-recognized or are believed to have bigger potential. Well-designed remote sensing methods dedicated to a particular area can significantly assist in analysing the deposit potential as well as identify pollution. For such research areas, methods leading to the GIS database construction are proposed. Earth Observation imagery can be used for detailed waste materials mapping over the area of exploitation and ore processing. A lot of digital processing methods were developed for identifying zones with acid mine drainage, an important environmental problem posed by the mining community and caused by the oxidation-weathering of sulphides containing heavy metals. These methods could be further developed when used higher resolution optical data and hyperspectral data. Multispectral and hyperspectral images can be used for mineral mapping, the OH-FeOx anomalies and potential zones designation (for example for iron and other polymetallic mineralization). High-spatial resolution VNIR and SWIR spectral data can be employed to further differentiate and identify the presence of specific alteration minerals, often indicators of mineralization in subsurface. This in turn helps mining companies to focus on areas for further exploration (prior to expensive conventional methods such as trenching and drilling), thereby reducing fieldwork and minimizing environmental impact. An integrated structural fabric analysis from optical and SAR data may also help to narrow prospective target areas and bring down the costs for new discoveries.

The quantitative diagnosis of mine sites is a key-issue to deal with access and exploitation of mineral deposits, safety, remediation and recovery, where applicable, adequate mine closure planning. This diagnosis can be undertaken from remote sensing methods both optical and radar data, as well as geochemical and spectrometry methods. Remote sensing techniques are particularly suitable for the assessment and monitoring of mine sites due its synoptic perspective of overhead sensors, screening large areas and providing a spectral analysis at each pixel of the image, making it a cost-effective, non-invasive and relatively rapid technique when compared to traditional sampling methods. The main EO methods proposed for the raw materials studies are: space-borne radar and optical imaging, space-borne and airborne spectrometry, airborne LIDAR scanning and in-situ spectrometers, geotechnical and hydrological and hydrogeological data.

In the framework of the GEO-CRADLE project selected examples of the pilot studies sites, which present most interesting mining and post-mining areas, were analysed from the point of view of EO methods applicability. Through close cooperation with end-users in RoI, EuroGeoSurveys defined four different examples of pilot sites that allow to establish studies on better monitoring of the mining and post-mining areas and mitigation of their impact. It is expected that the methodologies elaborated on the pilot sites will have a universal character and could be applied for other RoI as well. We succeeded in elaborating the EO methodologies for legal and/or illegal quarrying in Greece, improved monitoring in abandoned Asbestos mine in Cyprus, carbon potential investigation and determination of orientation of coal outcrops in Central Anatolian

Lignite Basin in Turkey and determination of the iron potential zones in Celebi Iron-oxide mineralization district in Turkey. All of the pilot studies can be elaborated in the future, leading to the long-term collaboration between Geological Surveys of Europe and the government and research parties in the countries of RoI. In detail they are presented in four following chapters I-IV.

Access to Raw Material pilot end-users

ARM pilot established closer collaboration and extension of cooperation with the following end-users:

- Greece Ministry of Environment and Energy (YPEN): following consultation with the Ministry of Environment and Energy / Special Secretariat of Inspectors – Auditors / Body of Inspection for Southern Greece / Department of Mining Inspection, a close collaboration of the Geological Survey of Greece and the YPEN was launched in order to implement the pilot project in Greece. The selected specific pilot sites were proposed by the end-user, based on a number of criteria. The pilot application in Greece comprised the use of EO methods in mapping/monitoring of surface changes attributed to quarrying activities (legal and/or illegal) in order to establish a tool that may facilitate the monitoring of the respective quarrying activities and the mitigation of their environmental, social and economic footprint.

- Municipality of Alexandroupolis in Greece: an exchange of information upon the strong interest on establishing environmental monitoring of Ayios Filippos abandoned public mine of mixed sulphide ores (Kirki Village, North Greece) lead to the possible future collaboration with Geological Survey of Greece.

- Cyprus GSD-FD-Ministry of Agriculture, Rural Development and Environment: the scope of the feasibility study for monitoring of ground deformation and stability in the under restoration of the Asbestos Mine was established. The visit to the Asbestos Mine in Amiantos during GEO-CRADLE meeting in Limassol (16-17th, November 2016) organised by Geological Survey of Cyprus, allowed to evaluate the condition and plan the need for further work regrading use of EO data for unique multi-disciplinary large-scale mine rehabilitation project.

- Hellenic Copper Mines Ltd and Ministry of Agriculture, Rural Development and Environment: The visit to the Skourriotissa Mine during GEO-CRADLE meeting in Limassol (16-17th, November 2016) organised by Geological Survey of Cyprus led to the exchange of information on environmental monitoring before the closure of the mine and the possible use of EO data for Skourriotissa Village area. The Executive Director of the Hellenic Copper Mines presented application of bio-leaching and hydrometallurgy process including leaching and electro-winning for the production of 99,999 Cu cathodes. The exchange of information can lead to future collaboration with Geological Survey of Cyprus. Collaboration with Cyprus Ministry of Agriculture, Rural Development and Environment led also to defining the scope of possible use of EO data for prospecting secondary minerals from the Kokkinopezoula abandoned mine in Mitsero Village. The description of the issue in Kokkinopezoula has been found very interesting by Geological Survey of Cyprus and could lead to the potential future project.

- Minister of Energy, Mining, Water and Environment of the Kingdom of Morocco and Morocco stakeholders: 17-18 October 2016 in Rabat (Morocco) was organised an event “Addressing GEO-CRADLE regional challenges - Access to raw materials”, which included 2nd EGS Networking event “Aimed at in-situ network operators and Geological Surveys – especially in MENA” and Stakeholders’ workshop “Using geo-information services in MENA”. Both events gathered together local and regional in-situ network operators and Geological Surveys representatives. The event provided project partners and stakeholders with valuable knowledge on the identified regional EO capacities and skills, as well as the challenges in the domain of access to raw materials, and contributed to the refinement of the scope of the relevant GEO-CRADLE pilot activity focusing on the access to raw materials in the regions of Balkans, Middle East and especially North Africa.

- Geological Survey of Algeria and Algeria stakeholders: 19-23 October 2016 in Timimoun a part of 2nd EGS Networking event “Aimed at in-situ network operators and Geological Surveys – especially in MENA” was organised in the framework of the Algerian 5th National Stratigraphy Workshop. The event in Algeria was attended by over 200 participants representing the whole Algerian and North African geoscientific community, mainly from universities and governmental institutions at the highest levels. During the days of the congress various bilateral meetings were held, and requests by several institutions to start capacity building projects were collected. The workshop resulted in signing memorandum of understanding between EuroGeoSurveys and Geological Survey of Algeria.

- JADE - Association of Geological Researches, Turkey: Through previous cooperation in the field of research, we managed to establish contact in the Geo-CRADLE project. JADE proposed one of the test areas and was available during the entire pilot process. The results of the pilot can be used as a starting point for further cooperation in the area of coal deposits in Turkey.

- JeoDijital Bilisim Teknoloji Madencilik, Turkey: The company expressed interest in using remote sensing for environmental research and the potential of iron deposits in the Central Turkey. Consultations with the company lasted throughout the entire pilot phase.

1. GREECE

1.1. Identification of possible study

1.1.1. Name of the pilot site

Attica and Cephalonia quarries of aggregates and marble.

1.1.2. Summary

The Greek mining industry constitutes a major sector of the economic activity of the country (it constitutes 4-5% of the GDP, with the inclusion of interrelated enterprises such as quarrying, processing and production of intermediate and final products) **and supplies essential raw materials for primary industries,** such as cement, production of energy, non-ferrous metals (aluminum, nickel, etc), the industry of stainless steel etc. Moreover, the industry provides a major source of employment in the country, and because, as a rule, the processing of these raw materials takes place in the region in which they are excavated, the industry also contribute considerably to coveted regional growth.

Quality, safety and environmental protection, constitute significant challenges but also the most pressing needs of this era – deeply influencing not only the development of the mining industry, but also its traditional character of many centuries and finally its very existence.

In this framework, the issues of acceptance from local populations, corporate social responsibility, systems of quality control, and systems that allow collection and disclosure of full and accurate information (Databases, GIS, etc.) are all of particular importance.

The methodology described in the feasibility study can be applied for the Monitoring of Illegal Quarrying Activities in any place in Greece but also in any country in the Region of Interest.

1.1.3. Description of the pilot site

In the frame of WP-2 of this project and the consultation with end users in the thematic area of Raw Materials, people from the Ministry of Environment and Energy were interviewed. The Authority of the Ministry of Environment and Energy / Special Secretariat of Inspectors – Auditors / Body of Inspection for Southern Greece /

Department of Mining Inspection[1], described their needs that are related to the monitoring of Illegal quarrying activities.

A consultation has taken place and several sites have been proposed by the End User, to be included as pilot project areas.

These sites are located in Attica region and Cephalonia island (Fig. 1-1).

Fig. 1-1 Map of the pilot project areas in Greece - Extracted raw materials: Marbles, limestone aggregates

[1] *Ministry of Environment and Energy: Competent authority for the formulation, coordination and authorization of the implementation of the relative legislative framework and policies. The* ***Authority*** *is to be referred as* ***End User*** *in this report.*

1.1.3.1. *Attica region*

Attika region has several quarry areas some of which are in operation since ancient times (Penteli marble). They are located all over the region and some of them are around the city of Athens.

Specifically, the following 5 pilot project areas (Fig. 1-2), have been selected

1. Koropi: area: 2.5 km^2 illegal activity.
2. Markopoulo: area: 2.7 km^2 illegal activity, periodically active
3. Xyrorema(Quarries' Zone): area: 157.6 km^2 legal activity
4. Penteli (ancient marble quarries site): area: 22.4 km^2 occasional illegal marbles' exploitation.
5. Salamina island: total area of island: 80.7 km^2 illegal activity in the Northern part of the island

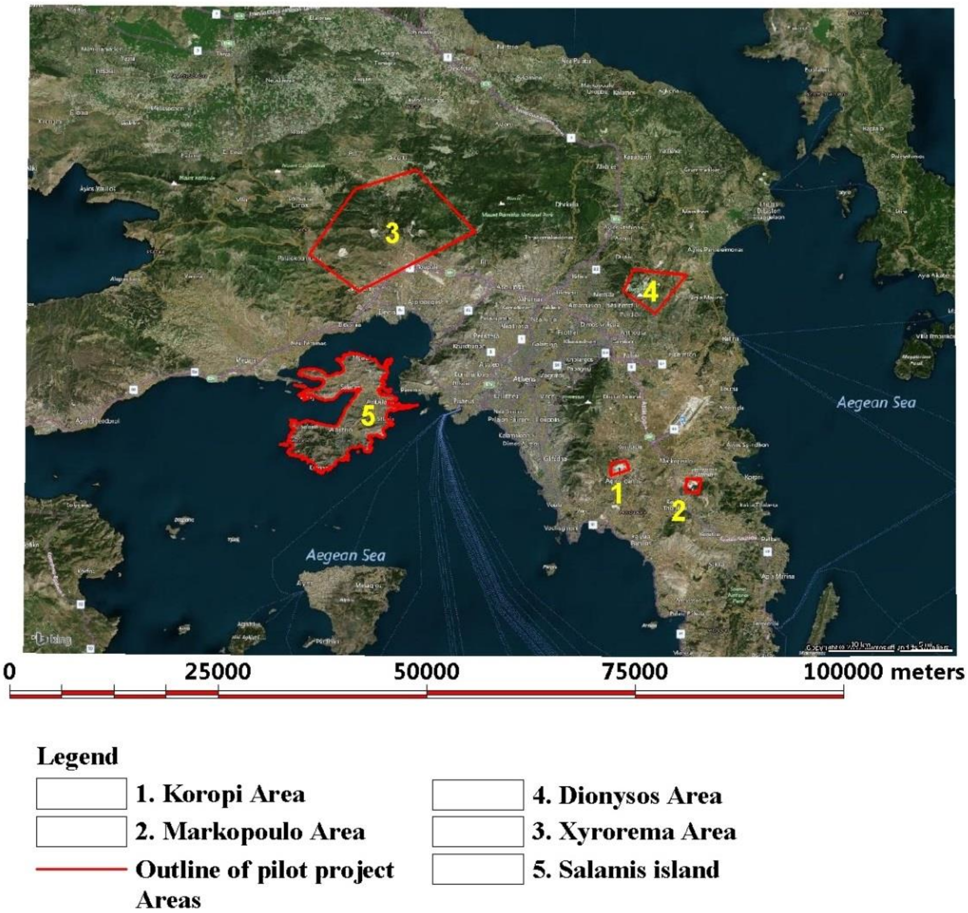


Fig. 1-2 Quarries in Attica

The geological setting of Attica is quite complex, implicating four main alpine geotectonic units (Papanikolaou et al 2004):

a) The lowest-basement unit (relatively autochthon) comprises the metamorphosed formations of Athens and can be found in Mount Penteli and Mount Hymettus. Formations include marble, dolomite, and mica-schist amongst others.
b) The Alepovouni unit found in the western side of Mount Hymettus, also characterized by metamorphic formations.
c) The Sub-Pelagonian unit, which can be found in Mount Egaleo and Mount Parnitha and consists of carbonate formations such as limestone and dolomitic limestone.
d) The Upper Unit of Athens which is basically found in all the internal part of the basin and is divided into two napes. The lower nape is considered to be a "mélange" and was often referred to, as the 'Athens Schist', whereas the upper nape is comprised of limestone.

Moreover, Pleistocene and Neogene deposits can be found in the region (Lekkas, S. and Lozios, S., 2000):

- Pleistocene deposits mostly consist of non-homogeneous inarticulate conglomerates and red clays. Their thickness varies from some meters to hundreds of metres. They are characterized by the presence of a calcareous crust, caused by the climatic influence.
- Neogene deposits are comprised by marls, sandstones, calcareous marls and conglomerates, with pebbles coming from marbles, schists, ultrabasic and pyrites. They often contain lignite intercalations.

1.1.3.2. *Cephalonia island*

In Cephalonia island there are various scattered sites, legal and illegal, active or periodically active. Based on 2009 data (IGME Report) 7 aggregates' quarries were under operation. Two quarries located near Sami and Lixouri cities have permits. Based on 2014 data, there is no Quarry Area defined in Cephalonia island, for aggregates' production. Apart from aggregate quarries, there is an important quarry operation on the island for the production of calcium carbonate operated by Ionian Kalk SA in Argostoli-Minies. Production of 130.000 tonnes and 15.000 tonnes of crude $CaCO_3$ Quality characteristics: >99,6% $CaCO_3$, <0,07% Al_2O_3, <0,02% SiO_2 και <0,01% Fe_2O_3.

The geological setting of Cephalonia Island as described by Karymbalis et. al. 2013 involves two main bedrock units:

(1) the east dipping, NW to NNW striking, thrust sheet fragments of a carbonate platform belonging mainly to the Pre-Apulian (or Paxos) geotectonic unit, and
(2) the Ionian unit occupying a relatively small part of the eastern island.

Pre-Apulian (Paxos) geotectonic unit consists of Cretaceous limestones and dolomites overlain by Paleocene-Eocene-Oligocene thick-bedded limestones. On top of them lie conglomeratic and brecciated limestones of Upper Oligocene to Upper Miocene age.

Ionian geotectonic unit consists of Pantocrator limestones of Upper Trias –Middle Lias age overlain by the Upper Lias-Middle Dogger age Ammonitico Rosso formation, which consists of thin bedded platy limestones with marly intercalations. Middle-Upper Dogger is represented by alternations of shales and limestones overlain by Vigla limestones with chert layers of Upper Jurassic –Lower Cretaceous age. On top of them Upper Jurassic –Lower Cretaceous breccias and limestones occur, while Paleocene and Eocene is represented by limestones.

Moreover, Neogene and Quaternary deposits are also present:

- Lower Pliocene: a short stratigraphic hiatus can be found and a transgressive well-bedded conglomeratic facies. These conglomerates are overlain by a limestone bed passing upwards into sand, sandstone and sandy limestone with layers of blue marls. Upwards, the blue marls predominate and enclose a rich mollusc fauna while in the uppermost part a series of fine-grained sandstones and sandy marls reappear.
- Pleistocene formations are composed mainly of conglomerates and sandstones.
- Holocene deposits consist of alluvial fans, scree, and high-energy fluvial deposits mainly deposited along the stream channels as well as solution depression fillings consisting of terra rossa and fluvial sand and gravels.

1.1.4. Description of existing data

Main sources of information are:

- IGME for the 1:50,000 scale Geologic maps
- Geographical Service of the Army for the topographic data of 1:50,000 and 1:5,000 scales
- The EU Copernicus service http://land.copernicus.eu/pan-european

The pan-European component is coordinated by the European Environment Agency (EEA) and produces satellite image mosaics, land cover / land use (LC/LU) information in the CORINE Land Cover data, and the High Resolution Layers.

The CORINE Land Cover is provided for 1990, 2000, 2006 and 2012. This vector-based dataset includes 44 land cover and land use classes. The time-series also includes a land-change layer, highlighting changes in land cover and land-use. The high-resolution layers (HRL) are raster-based datasets which provides information about different land cover characteristics and is complementary to land-cover mapping (e.g. CORINE datasets or Natura 2000 data, http://ec.europa.eu/environment/nature/natura2000/index_en.htm).

Geological, topographic and land cover data are available in various scales and formats, Fig. 1-3.

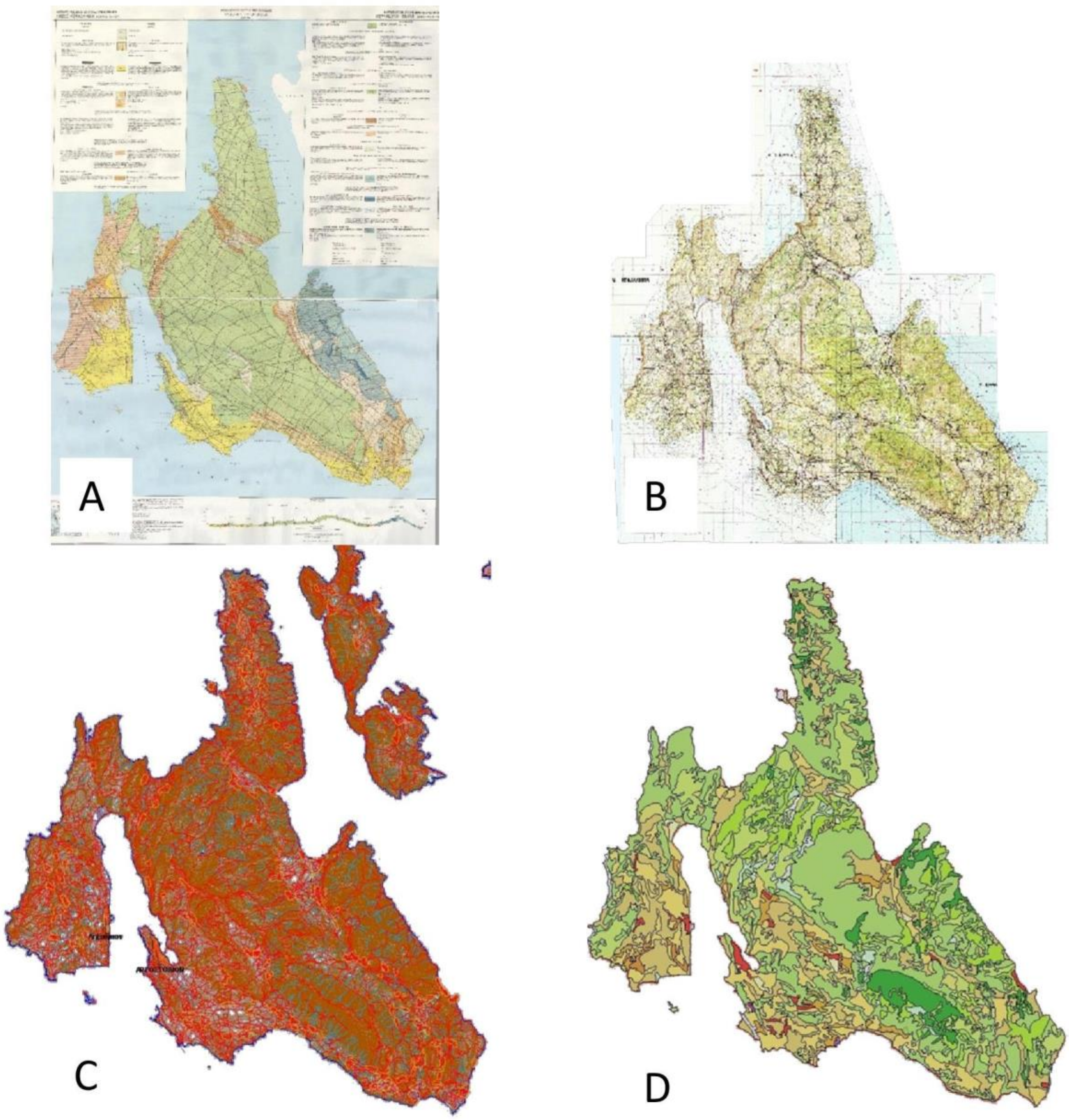


Fig. 1-3 Geological maps are available by IGME in a scale 1:50,000 as raster Geotiff formats (A) Topographic maps are available in raster formats (B) or vector formats (C) in scales 1:50,000 and data of "Corine Land Cover and Natura" projects (D).

The information shown on Corine land cover data in relation to "Quarries" is limited due to the mapping scale which is 1:100,000, Fig. 1-4.

Fig. 1-4 Left figure: One mining extraction site is shown in A. Right figure: Active & Inactive quarries as shown on IGME report 2014

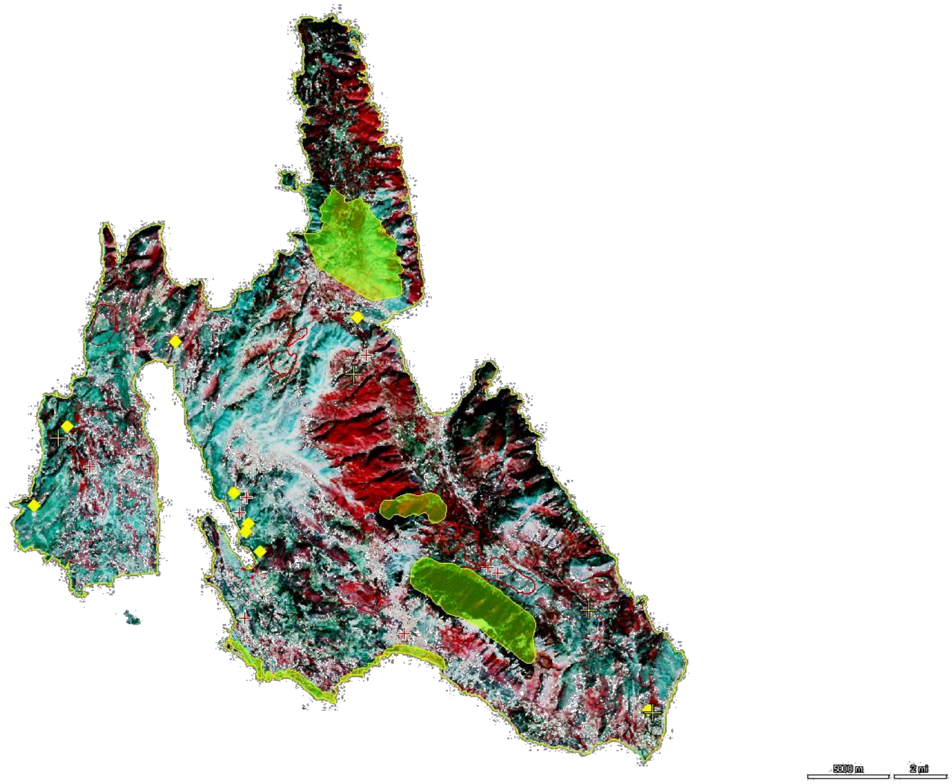
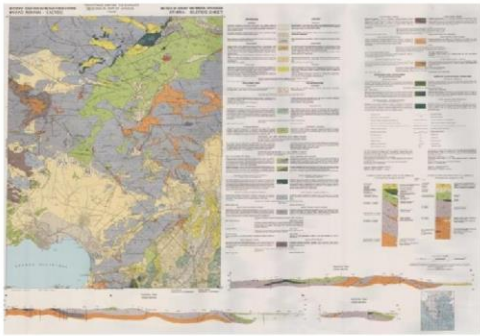


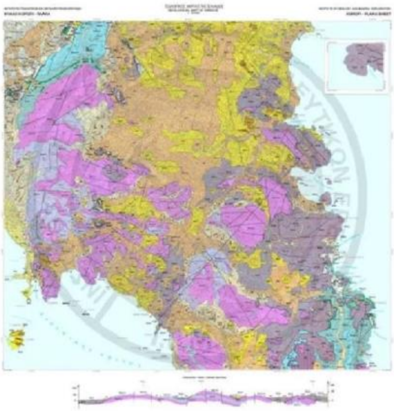
Fig. 1-5 Additional data concerning the mapping of quarries on the Island are available by IGME and these have been analyzed along with the acquired Earth Observation data.

Similar types of data are also available for Attica region (Fig. 1-6).

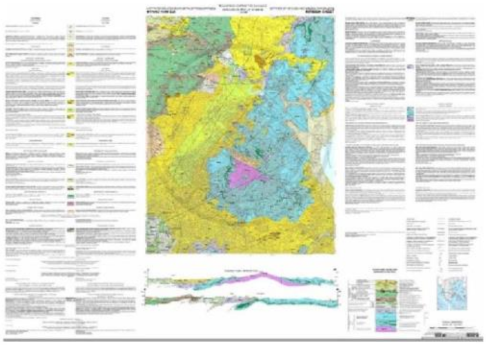
Athena Piraeus Sheet



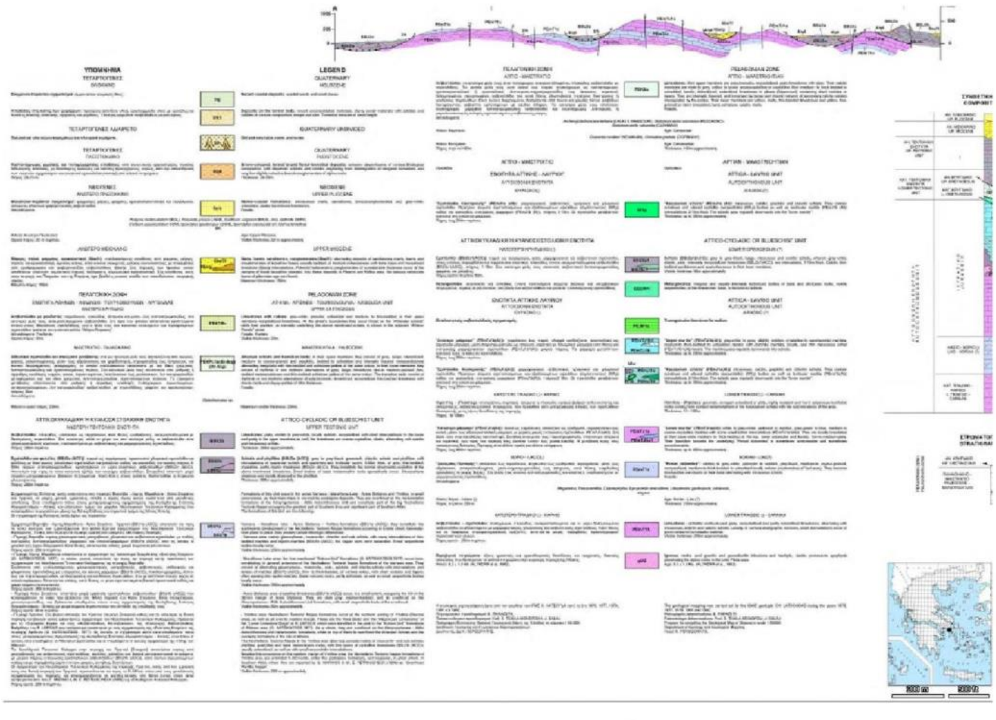
Athena Eleusis Sheet



Koropi Sheet



Kifisia Sheet



Legend Koropi Map Sheet

Fig. 1-6 Available Geological Sheets in scale 1:50,000 of Attica region

Two types of data are also available for the pilot project areas:

1. Digital Elevation Models (A) and Ortho-photos (B) provided by National Cadastre and Mapping Agency –NCMA http://www.ktimatologio.gr/sites/en/Pages/Default.aspx Ortho-Photos are of 1 meter resolution and therefore they cover needs for inspections. However, there are limitations related to the temporal resolution as they are not updated yearly.
2. Ortho-photos provided within TNTgis S/W like Bing maps (C) in Fig. 1-7.

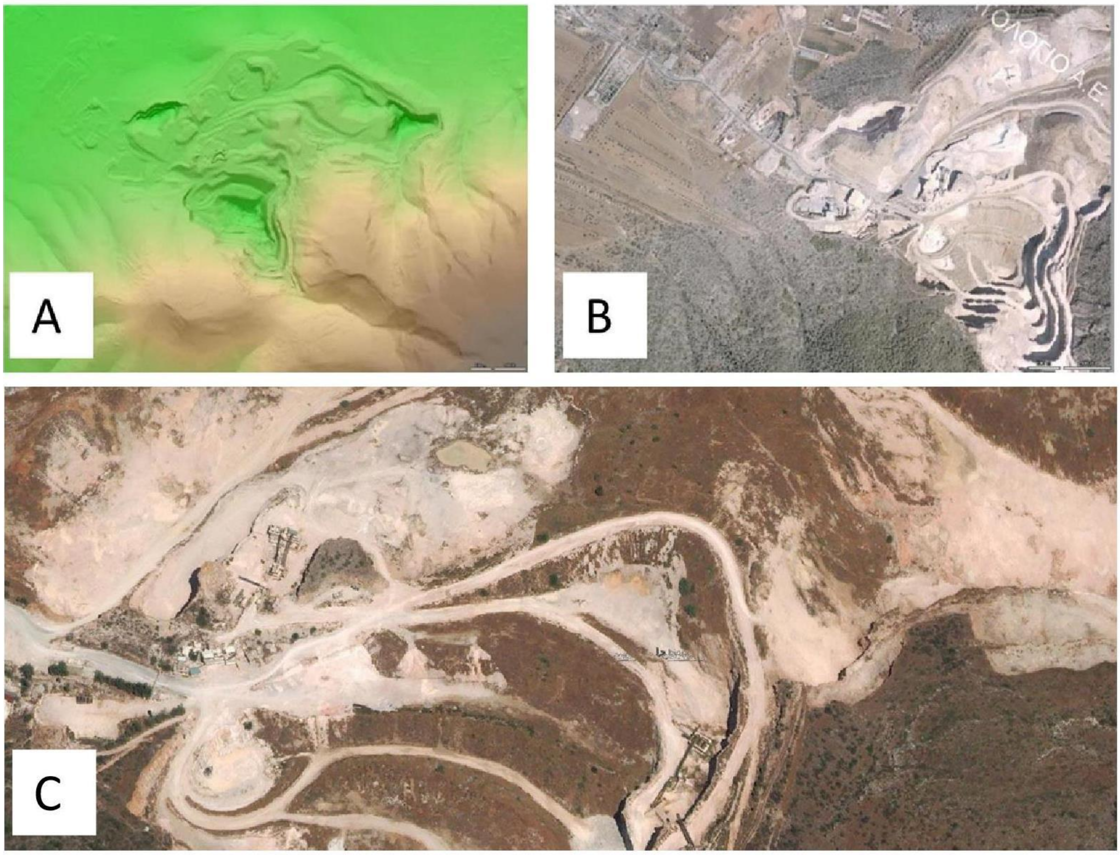


Fig. 1-7 Detail of Digital Elevation Model of 5 meters resolution (A) Ortho-photos of NCMA (B) and Bing maps ortho photo (C) integrated within the GIS system - Google Earth can also be synchronized as an external viewer in the GIS system.

Ministry of Environment and Energy is holding maps in GIS format in which the boundaries of the quarry pits (the area of active extraction) are identified. These data are published on LATOMET: http://www.latomet.gr/lp_adranon/. Different Departments of the Ministry of Environment monitor quarry areas through evaluating ortho-photos obtained from the National Cadastre and Mapping Agency –NCMA. Some mining data are also available by the End User. There is no information on possible access to previous (present) monitoring data (geodetic, hydrogeological, geochemistry etc.)

In this respect it is indicated that satellite data are needed in order to establish a monitoring system. After the consultation with End User it has been indicated that a medium resolution satellite system could cover their initial needs. Sentinel 2* satellite system has been selected to be evaluated for "monitoring quarry areas", Fig. 1-8.

Sentinel 2 data can be used for monitoring local processes as its specifications are comparable but with enhanced features in relation to other satellite systems like the Landsat series. The data are freely available to the scientific community.

Sentinel-2 mission overview

The Sentinel missions are designed to provide routine observations for operational Copernicus services and to provide data continuity of ERS, ENVISAT and multispectral missions such as SPOT, Landsat, ASTER, etc. Sentinel-2 carries a super-spectral instrument with a sun-synchronous 786 km orbit that allows covering all the land surfaces and coastal waters between -56 and +84 degrees latitude with a 290 km swath width at a 10 days revisit time at the equator (5 days revisit time at the equator based on 2 satellites). The mission is primarily designed for land cover and associated applications in change-detection mapping. A variety of variables (e.g., leaf chlorophyll content, leaf water content, leaf area index;) is proposed for Sentinel-2 as inputs to earth system models. The provision of long-term data with the Sentinel missions is a prerequisite to allow better understanding of climate variability. In addition, long-term data continuity is a pre-requisite for fostering downstream services that Sentinel-2 provides for example in the areas of European land use / land cover changes, food security early warning and global change issues. Sentinel-2 delivers level 2 geochemical / physical data products and level 3 biophysical variables which are physically consistent and reproducible which implies with limited empirical (and ground-based) studies these data products can be incorporated in global process models.

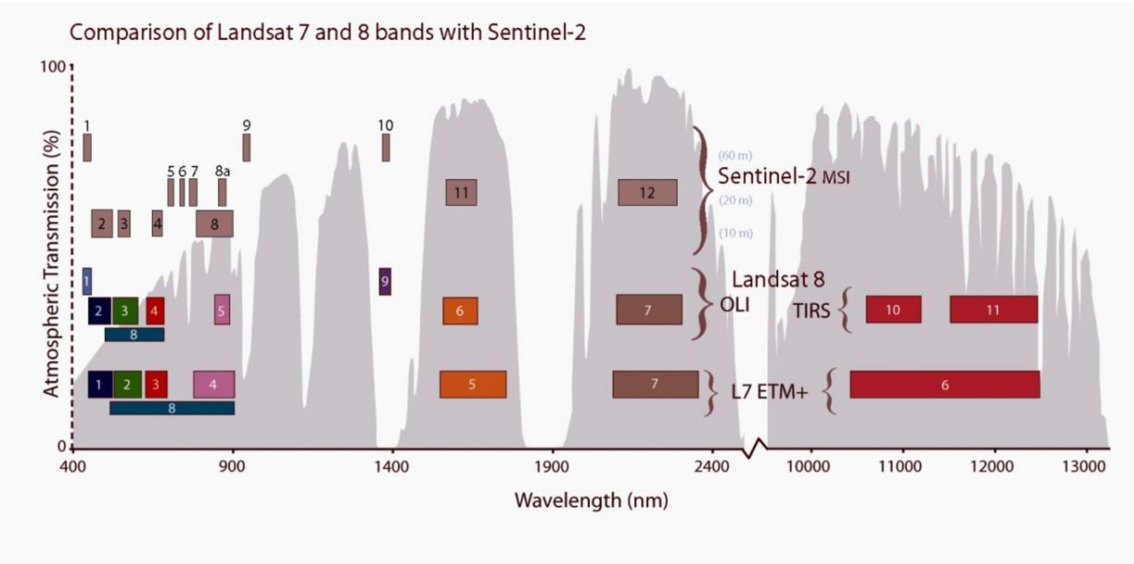


Fig. 1-8 Sentinel 2 systems covers 13 different spectral bands with a resolution ranging from 10 to 60 meters.

During the consultation process with the End User it was indicated that Very High Resolution satellite data may be needed. WorldView satellite images (WorldView-2 imagery is a "satellite image ©2017 DigitalGlobe") have been also used. DigitalGlobe's WorldView-2 satellite sensor, launched October 8, 2009, provides 0.46m panchromatic (B&W) mono and stereo satellite image data. The WorldView-2 sensor provides a high resolution panchromatic band and eight (8) multispectral bands; four (4) standard colors (red, green, blue, and near-infrared 1) and four (4) new bands (coastal, yellow, red edge, and near-infrared 2), full-color images for enhanced spectral analysis, mapping and monitoring applications.

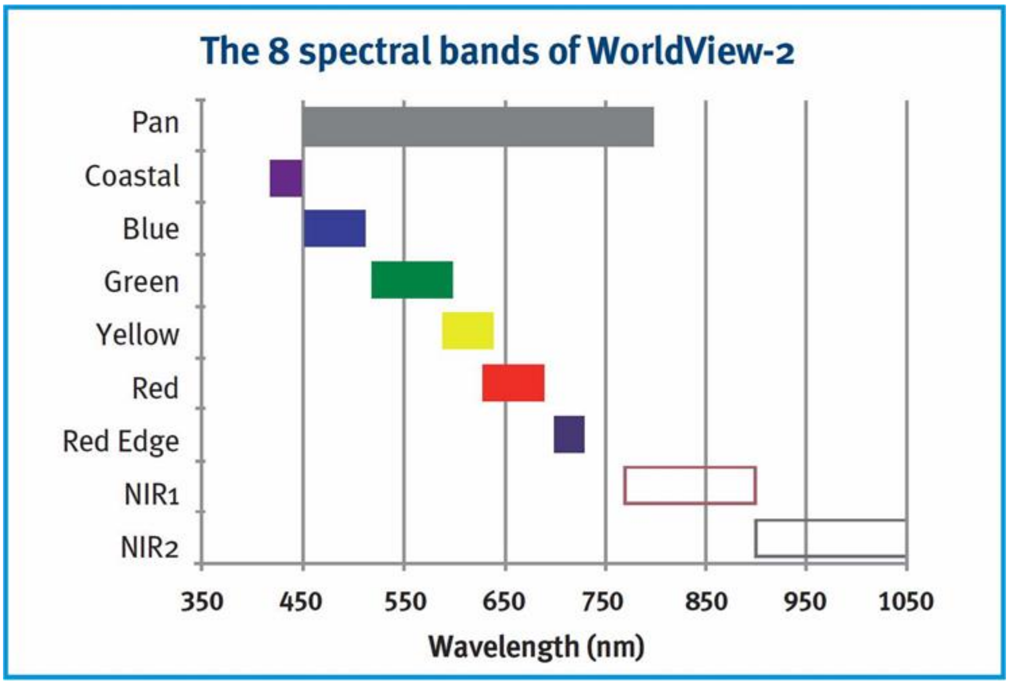


Fig. 1-9 The diagram presents the WorldView-2 8 bands.

Further information concerning the WorldView-2 data can be found on:

https://www.digitalglobe.com/about/our-constellation

https://www.satimagingcorp.com/satellite-sensors/worldview-2/

http://satimagingcorp.s3.amazonaws.com/site/pdf/WorldView_2_Overview.pdf

*The satellite image has been made available to us by:

"TotalView (www.totalview.gr) & European Space Imaging (http://www.euspaceimaging.com)".

This is kindly acknowledged.

1.2. Project description

1.2.1. Objectives and expected results

Regarding the monitoring of quarrying activities there are three different types of activity that need to be surveyed: (a) Exploitation of 'quarry minerals' in quarry sites with valid permits; (b) Potential illegal activities taking place in abandoned or without an active permit quarries, and (c) Occasional extraction activities in unpermitted sites.

Within these, illegal quarrying requires close surveillance and monitoring due to a number of side effects presented below and constitutes a permanent need of the competent authorities and a request on behalf of the industry.

Illegal quarrying activities vary from small scale excavations, occasionally operated by individuals in order to extract aggregates for their own use, to operations usually performed within already existing quarry sites developed at various scales. The latter operate usually for a few months and are not easily controlled by local authorities.

It is well documented that illegal quarrying activities are related to severe economic, social and environmental impacts affecting not only the restricted area where such activities take place, but also wider areas. This problem was particularly highlighted by UEPG (the European Aggregates Association) as well as project partners, during the implementation of two EU co-funded projects, SARMa and SNAP-SEE that covered the geographical area and countries of South East Europe.

Exploitation of aggregates in Greece is generally only permitted within the defined Quarrying Areas (QAs)[2]. In certain cases, exploitation permits can be granted for quarries that are located outside the QAs (article 8 of Law 2115/1993) such as, exploitation of aggregates for specific uses (e.g. for anti-slippery road construction), public infrastructure works and when it is not possible to define a QA as e.g. in islands etc. The delineation of QAs, where aggregate quarries are permitted, is a completely decentralized procedure since 1984 (Law1428/1984 & Law3852/2010).

It is difficult to estimate the actual quantities of aggregates deriving from illegal activities, since relevant official data are not always available. Nevertheless, it is estimated that only 50-55% of the total aggregate production in Greece comes from established Quarrying Areas (QAs). The rest is either due to illegal quarrying or due to quarrying based on various exceptions of the legal framework.

[2] *QAs: Are legally bounded areas, where mineral raw materials are extracted for aggregates' production, determined at Regional Level. QAs consist the legislative tool for the planning and sustainable development of primary mineral raw materials for the production of aggregates. They are determined with a decision issued by the competent, by case, Regional Governor, after consultation of an 8-members Committee with representatives from different authorities.*

Illegal activities are often practiced in areas of abandoned and not properly restored quarries. Moreover, abandoned quarries are amenable to illegal disposal of various types of wastes.

Illegal operators do not employ health and safety rules for extraction. Therefore, serious risks stem for both the safety of the illegal operators as well as, for the surrounding environment, settlements and habitants. Also, illegal operators do not apply appropriate and environmentally friendly methods/techniques for extraction since they are usually not professionals and unauthorized. On the contrary, their usual practice is predatory extraction, accompanied by uncontrolled disposal of ‘waste’.

Illegal quarrying activities have negative economic impacts at local, regional and national level since illegal operators do not pay taxes or other fees/royalties envisaged for permitted quarries. Furthermore the quality characteristics of the illegally transported products are not regularly checked and therefore may not conform to all specifications.

The absence of or the difficulty to delineate a Quarrying Area e.g. on an island (due for example to limited availability of space and/or the coexistence of touristic activities) in combination with the difficulty to develop a safe and at low cost transportation of aggregates from nearby locations, may “facilitate” illegal quarrying activities.

The lack of studies on the medium to long term market needs for aggregates at local level in combination with complicated and time consuming permitting processes may also “encourage” illegal quarrying. It is required studies for the delineation of “Quarrying Areas” to be accomplished in several areas including the Greek islands.

Another factor that “encourages” illegal quarrying activities, is the lack of efficient and consistent monitoring processes and tools employed by the competent authorities.

In some locations quarrying may result in excessive environmental or community impacts, and when conducted illegally, it contributes to a loss of the social license to operate for quarrying companies.

Besides the need to identify any unpermitted interventions for exploitation, the competent authorities for the issuance of permits and the surveillance of the compliance to the terms and conditions included in the permits, need to monitor and survey all permitted operations on a regular basis. This includes monitoring rehabilitation activities in active legal mines. So far these surveys are mainly carried out via in situ autopsies, which is a time, cost and effort consuming process. Considering the under-staff status of the authorities, an alternative methodology has to be examined and tested for an efficient monitoring of the overall quarrying activities.

Through the close collaboration of the Geological Survey of Greece (IGME) on one hand and the Ministry of Environment and Energy[3] / Special Secretariat of Inspectors – Auditors / Body of Inspection for Southern Greece / Department of Mining Inspection on the other, (the latter acting as end user), several pilot sites were proposed, based on a number of criteria such as:

(1) Areas hosting intensive quarrying activity regarding exploitation of: i) mineral raw materials for the production of aggregates; ii) industrial minerals, and iii) marbles and other ornamental stones. Amongst these, the aggregates' mineral raw materials exploitation consists a core activity that is more susceptive to illegal activities;
(2) Regions where legally bounded areas for the exploitation of aggregates have not been delineated yet and in which the needs for aggregates' consumption is high (e.g. islands, densely populated urban areas);
(3) Remote areas which are not easily accessible for regular in situ inspections (e.g. islands);
(4) Limited number of granted aggregates' exploitation permits, to cover the actual needs;
(5) Areas where illegal quarrying activity has been noticed or suspected.

The pilot application in Greece comprised the use of EO methods in mapping/monitoring of surface changes attributed to quarrying activities (legal and/or illegal). A long term objective will be the establishment of a Tool, with the use of EO data, which could facilitate the competent authorities in monitoring illegal quarrying activities. This Tool may be used to track any detectable potential changes of surface morphology, land use, etc. related with such activities.

The methodology to be developed could be applied for the Monitoring of Illegal and Legal Quarrying Activities and eventually the mitigation of the environmental, social and economic footprint in any country in the Region of Interest. It targets policy and decision makers and generally the competent authorities at all levels, which are in charge of development and implementation of policies as well as the authorization and inspection of quarrying and mining activities.

1.2.2. Methodology, methods of implementation

Environmental monitoring is now an integral part of mining operations. Remote sensing data enables the identification, delineation, and monitoring of quarry areas, including derelict land, and changes in surface land use. The aim of this pilot site is to evaluate the use of Earth Observation and in particular of the multi-temporal Sentinel 2 data to map and monitor quarry areas on a local scale, and to assess the

[3] *Ministry of Environment and Energy: Competent authority for the formulation, coordination and authorization of the implementation of the relative legislative framework and policies*

quarrying activities by indicating the changes on land. The case studies of Attica region & Cephalonia Island are presented. The general Plan of the methodology applied for this Pilot Site is shown in Fig. 1-10 and it includes:

- Mapping and monitoring (Change analysis / track any detectable potential changes of surface morphology) based on satellite Sentinel-2 data.
- Validation of the status of Quarrying activities on the pilot project areas with available data by the End-User and mainly by the LATOMET database http://www.LATOMET.gr/ypan/)
- Identification of illegal quarrying activities which are to be archived by developing a Monitoring System (Tool) with the use of EO data.
- Evaluation of rehabilitation activities on quarry areas
- Evaluation of the contribution of Earth Observation data on supporting studies for the identification of Quarry Areas and supporting inspections by the End User.

** Project Title: Integrated management of ornamental stones, aggregates and exploitation. Wastes-techniques for alternative use of inactive quarries. Project Coordinator: D Bitsios IGME, Community Support Framework 2000-2006, Project Participants: IGME, Part of the work has been awarded to contractors NERCO ltd, ECHMES Ltd, Duration: October 2003-2009.*

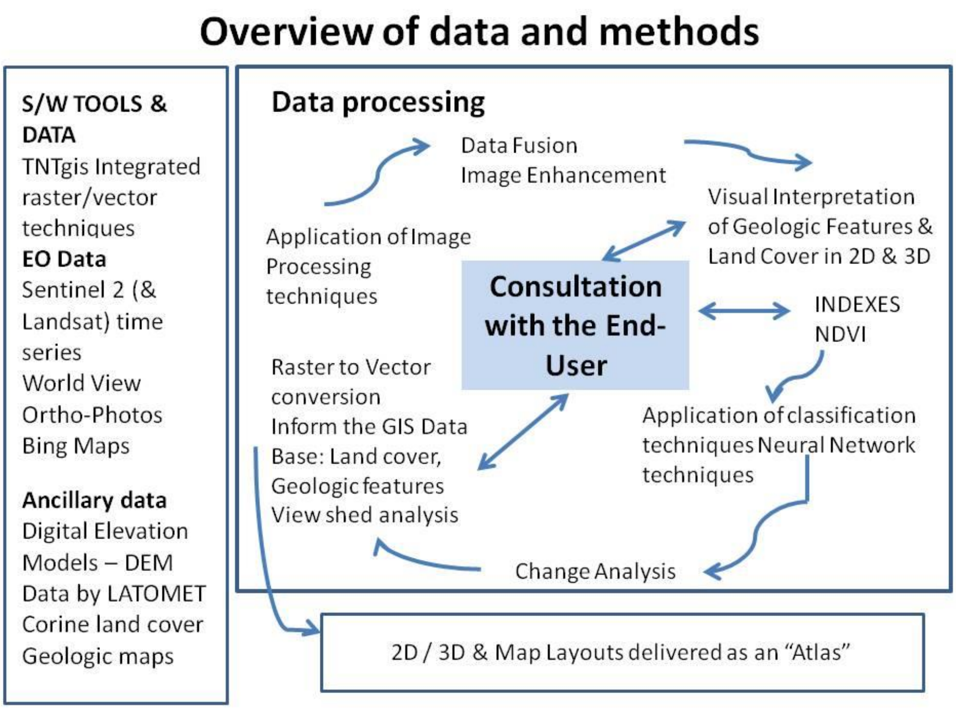


Fig. 1-10 Overview of overall plan of the Greek pilot site of "Data and Processing techniques"

Initial processing for change analysis and monitoring is based mainly on satellite Sentinel-2 data using time series data for the period of 2015 to 2017 for the pilot project areas of Attica region & Cephalonia Island.

The developed methodology could be applied for the Monitoring of Illegal and Legal Quarrying Activities and eventually it could be used for the mitigation of the environmental, social and economic footprint in any country in the Region of Interest. It targets policy and decision makers and generally the competent authorities at all levels, which are in charge of development and implementation of policies as well as the authorization and inspection of quarrying and mining activities.

1.2.3. Main activities

The basic S/W tool used for the integrated analysis of both raster and vector data is the TNTgis software. Research has been accomplished following step by step analysis including (1) Pre-processing of EO data, (2) Image processing, (3) Application of classification techniques, (4) Application of GIS techniques, (5) Application of techniques for the distribution of processed information.

Consultation with the End User in every stage of analysis has been carried out so as to identify its needs. The feedback gained during the consultation has been integrated in the various stages of analysis so as the analysis of the Earth Observation data to cover User's Needs.

Various image processing and vector GIS techniques are used for the analysis of the satellite imagery and the collected map data.

Pre-processing

Identification of areas of interest with respect to quarries as this has been identified by the End User. Acquisition of multi-temporal data has been carried out for all quarry areas for the years 2015, 2016 and 2017. Application of atmospheric correction techniques.

Georeferencing and resampling: The images used were geodetically corrected into the Transverse Mercator Projection using the Hellenic Geodetic Reference System (HGRS’87) as this is required by the End User. Resampling was carried out using the bi-cubic method.

Image Processing

Colour composites: Various pseudo-colour composites like the RGB-843 have been used of the Sentinel 2 data in order to emphasize the quarry areas, which have high spectral reflectance. The composites accentuated the quarry areas and discriminated vegetation from barren soil.

Decorrelation stretch

Intensity hue saturation (IHS) images: different resolution data were combined using data fusion techniques. This was effective for the land cover and the interpretation of geologic features because complementary information for the same target area was combined. The IHS transform was used to fuse the bands of higher panchromatic spatial resolution with the multispectral bands of the Sentinel 2 images so that the inherent land cover classes in the quarry areas could be identified. PCA has been applied of the bands with higher resolution for data noise reduction, while PC1 component has been used as the panchromatic image -PAN in the data fusion process. Final image products derived from this procedure was the 8,4,3-PAN composites.

NDVI calculation for vegetation and masking

Map layouts in 2D or 3D formats and as Stereoscopic images using the available Digital elevation Models

Classification

Image Classification - Unsupervised classification techniques using neural networks: Artificial Neural Networks (ANNs) are generally quite effective for the classification of remotely sensed data (Vassilas and Charou 1999). For classification purposes, the SOM- Self Organizing Map ANN method was used on the Sentinel 2 images in order to discriminate all inherent land cover classes of the satellite images. Different land cover types were mapped in the quarry areas and the surface extent for each cover type was estimated.

Automated combination of the classification result of multi-temporal imagery: Automated conversion of raster to vector data: the raster output of the classification and/or interpretation process was converted to vector data and these data were analysed with the corresponding map data and observation acquired on the Ortho-photos Fig. 1-11.

Processing and analysis: further processing and analysis was performed to derive information concerning changes identified in pilot study areas.

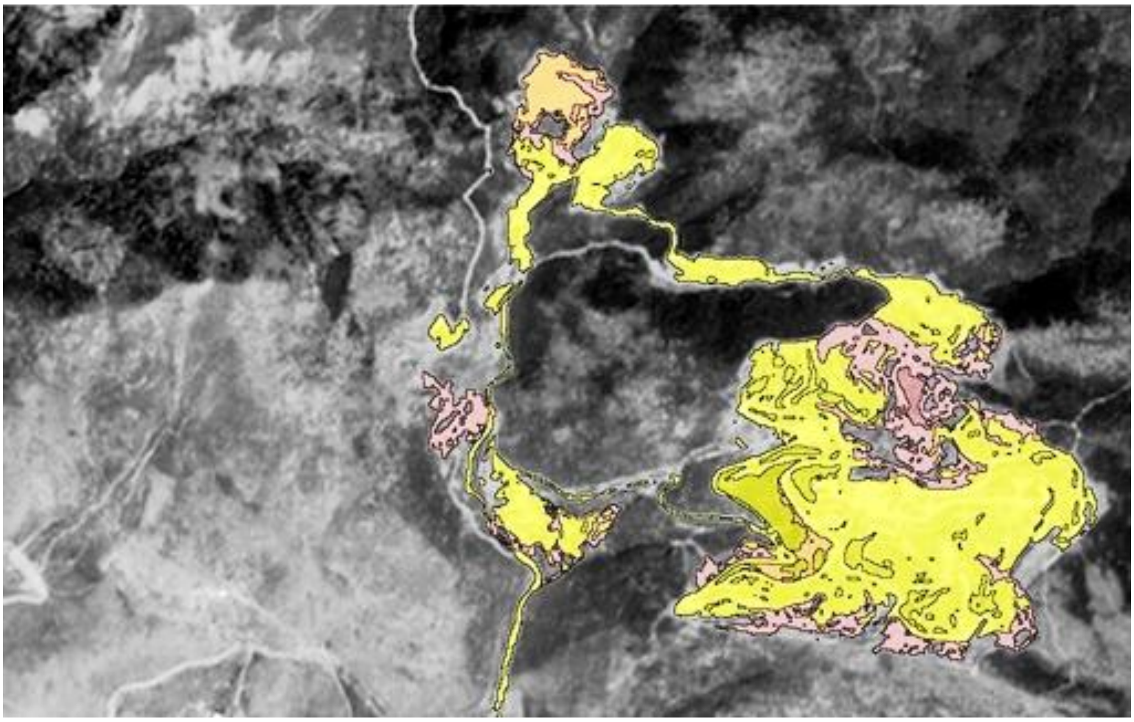


Fig. 1-11 Image classification: Coloured polygons are related to surface activity of quarry area.

GIS techniques

Collection, input, coding, storage, management, retrieval of various data: all ancillary data (raster, vector, ASCII) selected in this study are aggregated in the GIS in order to assess quarrying activities. Extraction of the topographic variables (shading relief, slope & aspect) and View shed analysis have also applied.

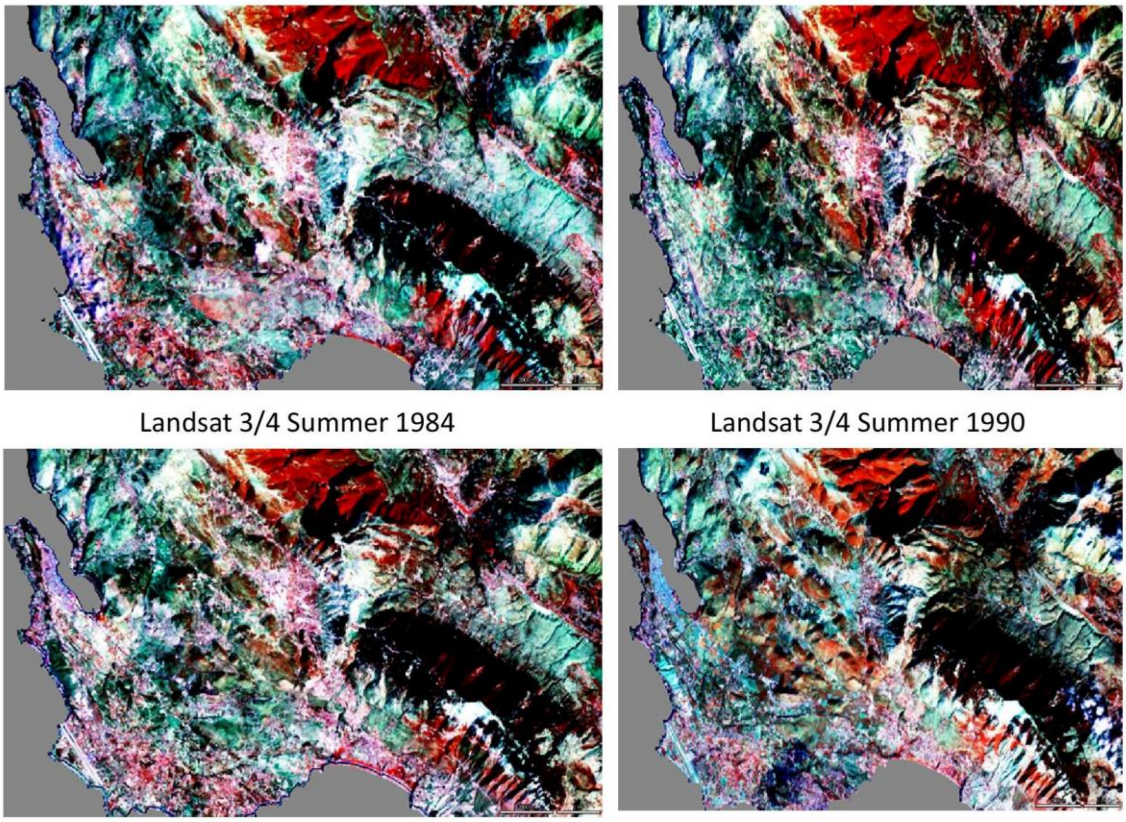
Dissemination of information

There is a need to disseminate information of collected and processed Earth Observation and GIS data using electronic means which are to be dedicated to cover the End User needs. Presentation and display, map making, and distribution of information using free software (freeware) is needed to be functioning on End Users premises.

1.2.4. Results of the pilot site analysis

All 7 quarries of the Attiki region, along the 9 quarries of aggregates and the 9 inactive of the Cephalonia island, have been analysed. In summary the following have been identified:

- Changes of surface area of quarries
- Disposal of waste material / Deposition areas
- Changes of vegetation cover
- Change analysis has been very sensitive to acquisition date of the satellite data and to shadows due to intense relief of quarry areas.



Landsat 3/4 Summer 1984 Landsat 3/4 Summer 1990

Landsat 7 Summer 2000
Pan sharpen

Landsat 8 summer 2011
Pan sharpen image

Fig. 1-12 Landsat Time series data

Evaluation: Monitoring of quarry areas for a time interval of more than 35 years is supported using the Landsat TM time series data. For example it is shown that the extraction activity in the quarry with the industrial minerals has been intensified after 2000. Also the existence of quarries established before the 1980s can be verified. Inspectors can get an overview of the quarry activity for a time interval more than 35 years. Quarry areas can be identified visually, but no quantitative evaluation of the surface areas can be estimated for the quarries with smaller size, due to the low resolution of the images.

Comparison of the spatial resolution of Landsat images with Sentinel 2 has been carried out. Areal extend of quarry areas can be accomplished more effectively on Sentinel 2 than Landsat data due to improved spatial resolution and this has been verified by the End User.

Integrated analysis

Different types of collected data have been analyzed and in particular the data of LATOMET data base.

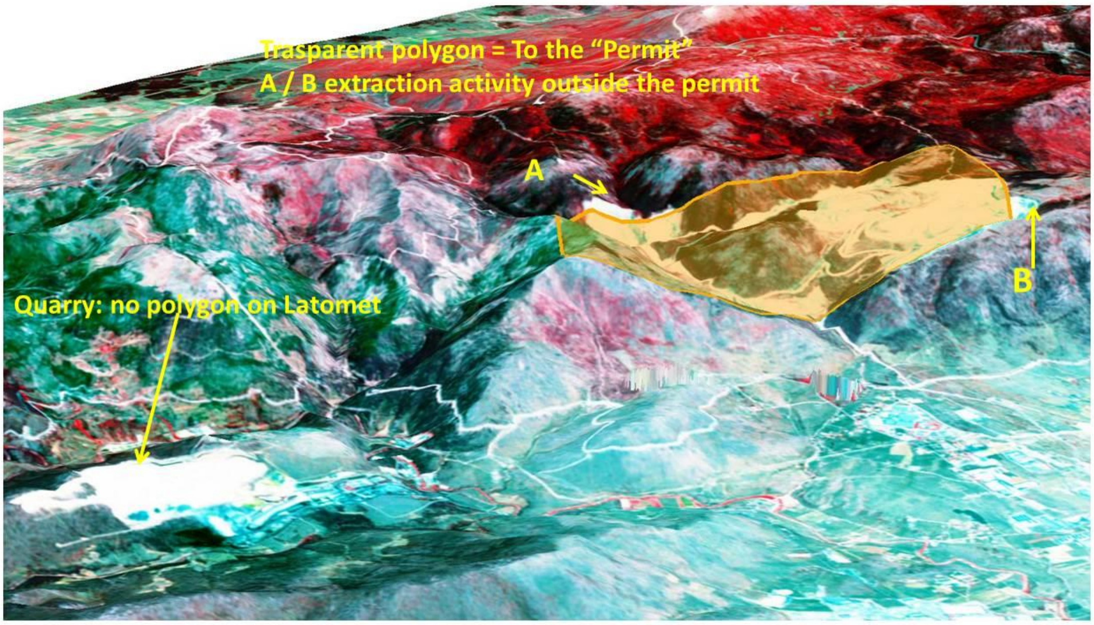


Fig. 1-13 Xsirorema quarry area with two main quarries: One quarry area is defined on LATOMET Database but it is shown that "activity" takes place outside the permit. The second quarry even though is active; no spatial outline of the permit has been defined.

Preliminary results

- Monitoring is supported through change analysis / The methodology can support the periodic field inspections of "the quarry and / or quarry operator" to ensure national regulations are met.
- Temporal resolution of Sentinel 2 data cover needs of the End User. Regular updates of all quarry areas of Greece are required (Once or twice per year).
- Spatial resolution of Sentinel 2 data covers needs for "regional monitoring" of surface mapping of the outline of quarries for the whole of country.

High resolution satellite data

Quarries with surface sizes less than 0.5 km² can be mapped on Sentinel 2 data. Activity on the quarries can be monitored while a general evaluation can be accomplished. However, it is also shown that there are restrictions in using Sentinel 2 data due to its medium resolution and key features related to inspections cannot be recognized easily while misinterpretations can also occur. This is why a third example has been carried out using WorldView-2 data for a quarry area located in Northern Greece.

High resolution WorldView-2 data have been evaluated. Sentinel 2 have been compared with the WorldView-2 satellite image for the same area and results are shown on Fig. 1-14 – 1-16.

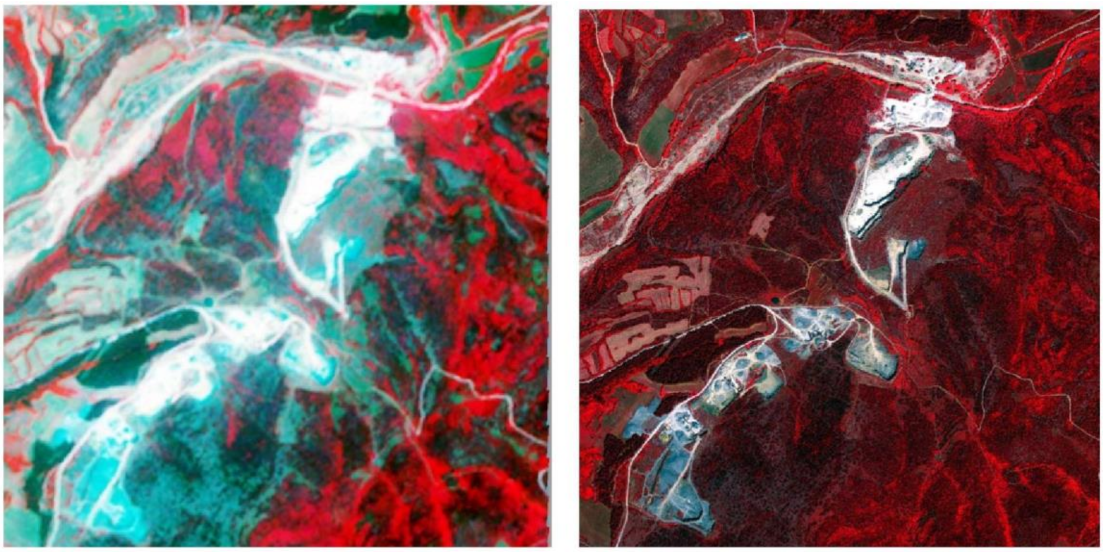


Fig. 1-14 Sentinel 2 - left image vs WorldView-2 - right image

Fig. 1-15 Sentinel 2 - left image vs WorldView-2 - right image; Scale 1:2,000.

Fig. 1-16 Sentinel 2 - left image vs WorldView-2 - right image; Scale 1:1,000.

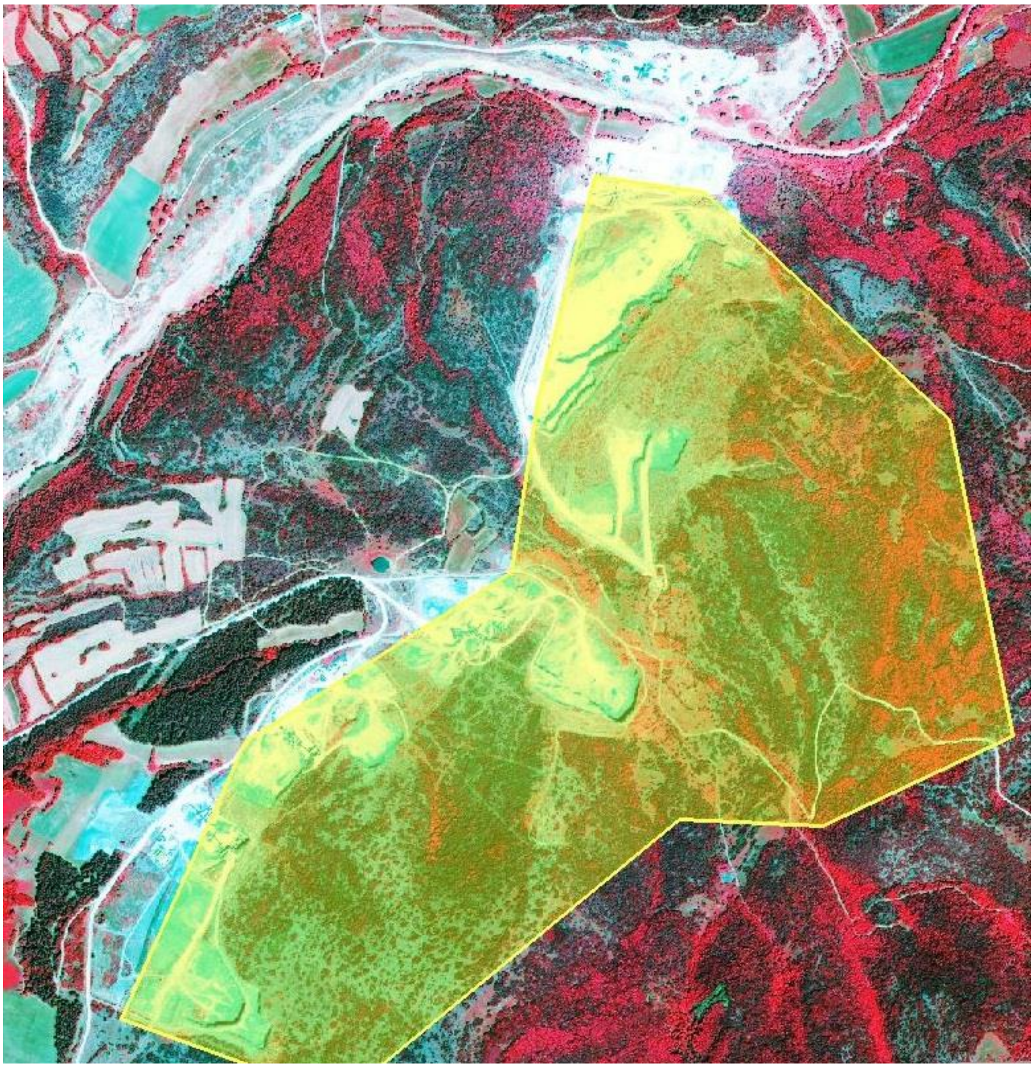


Fig. 1-17 Transparent polygon: Permit as given on LATOMET

Visual comparison of Sentinel 2 with WorldView-2 images shows that the high resolution data can contribute to enhanced mapping and monitoring of Quarries Fig. 1-17 in scales up to 1:1,000. Therefore, certain “quarry inspection cases” have to be based on high resolution satellite data. Acquisition of 3D data may also be required to be obtained using satellite or UAV airborne photogrammetric methods in order to get the third dimension of the depth of excavations.

EO tools assist in mapping & monitoring surface quarrying activity –The legal aspects of the activities have to be assessed by the “Authority".

Monitoring rehabilitation NDVI

Consultation has taken place with End User in relation to the specific issue of monitoring rehabilitation activities related to changes of vegetation cover / reforestation, Fig. 1-18.

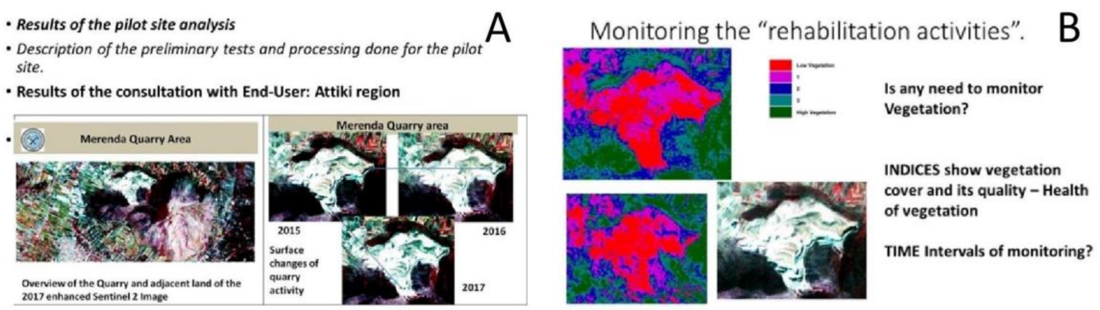


Fig. 1-18 Non active Quarry in Attica region (A) / Vegetation indices NDVI (B) in 2015 and 2017

Rehabilitation through reforestation on part of the quarry area has taken place and this can be mapped and monitored quite accurately. Monitoring of "reforestation" is particularly important to be carried out on active quarries as this is one of the parameters evaluated during the inspections.

Classification

Fig. 1-19 Consultation in relation to the application of image Classification techniques

During the consultation process it has been identified the need to automatically identify not only the surface extent of the surface area of the quarries but also to identify the different activities like deposition areas, waste disposal, active extraction surfaces, reforestation etc. Results need to be delivered in GIS vector format which can then be viewed with high resolution images. Results obtained from unsupervised classification techniques are quite satisfactory but there is a need for the End User to assign the relevant interpretations to the various classes. Supervised classification can also be carried out but the End User needs to define training sets of the various classes. Application can then be applied to all areas of interest and results are to be compared for the different acquisitions of the Earth Observation data. The following analysis is then the same as with the application of unsupervised classification techniques.

Despite important algorithmic developments in recent years, there is still no universal and optimal recipe for remote identification, classification, and quantification of "quarry activities". In the past, linear spectral un mixing has received a great attention from algorithm developers, but so far, the outcomes have not been utterly convincing. Recently, un mixing has been augmented by incorporating the contextual (spatial) information, or by bringing nonlinear methods into the scene. The nonlinear un mixing methods may give more accurate estimates, whereas the spatial-spectral un mixing is exploited to incorporate the pictorial character of the image. It is anticipated that other types of hybridizations to be even more effective. There are many opportunities and promises in hybridization between spectral and feature domains.

Regarding the application of classification techniques, we have not gone far from traditional “image classification” approach, which is hardly comparable to the outcomes of visual techniques, while a system for automated identification of all the different types of "quarry activities" is still absent. Given the richness of contextual information embedded in quarry areas, in the form of texture or zoning, it is conceivable to use this valuable information using spatial-spectral hybrid techniques. Such a system should specifically adopted to analyze the spatial–spatial pattern, as well as the multiple wavelength spectral ranges. The use of ancillary data, which are essential for accurate spectral quantification, makes the processing techniques case specific and non-transferable. This limits the use of automating processing chains and the standardized (qualitative or quantitative) production of 'geo science products’.

View shed Analysis

Another issue that occurred during consultation process refers to the application of view shed analysis with the purpose to identify “visual pollution” of quarry areas. Integrated use of both satellite imagery and Digital Elevation Models with the application of View shed analytical tools can identify locations from which “quarry areas” can be viewed. This is particularly important during the Identification of New Quarry Zones by the 8-members Committee with representatives from different authorities issued by the Regional Governor as is the case of Cephalonia Island.

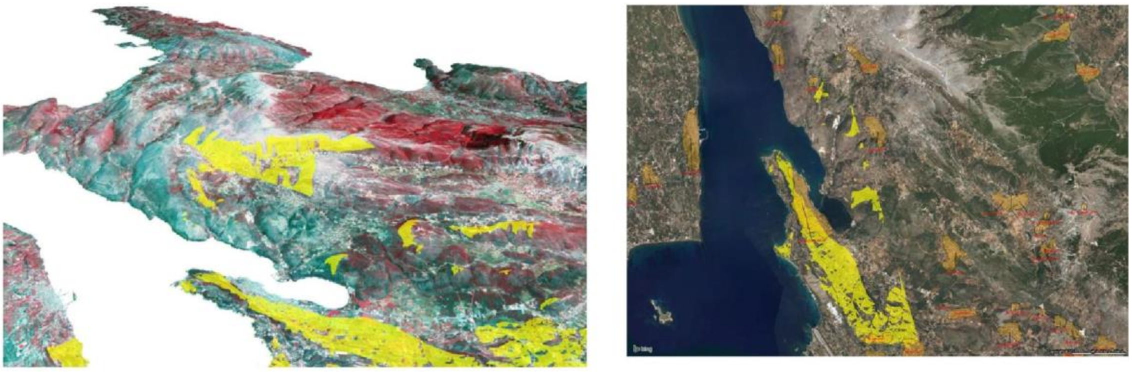


Fig. 1-20 Polygons with yellow color shows the areas which can be viewed by an observer on location X and on a building with certain height.

Identification of Quarry Areas

It is indicated that the developed methodology cannot only support the monitoring activities of the quarry areas but it can support the: "Poly parametric analysis of different data layers for the identification of New Quarry Areas – i.e. the designation of specific areas where quarrying and related activities may take place. This is particularly important for Cephalonia Island as the End-User is at the stage of identifying quarry areas. Recent earthquake activity has resulted on increased demand on Aggregate Materials for this particular island.

Dissemination of information

End User consultation also resulted in a need of making spatial information available to all staff members working on inspections in an easily used form of an atlas-like manner, Fig. 1-21. Computer users who have little training can then easily access and use the geospatial information. Main atlas capacities refer to establishment of objects and views so as to include all appropriate information of a stack of spatial information and display of multiple objects:

- Side-by-side (before and after views),
- Overlaying objects (vector and CAD lines of classification results over raster images / satellite images & ortho-photos on full spatial & temporal resolution),
- Include graphical symbol overlays (such as icons or pie diagrams), or additional reference information (like map grids, text blocks, and legends).
- Include object selection from spatially overlapping objects
- Easy navigation tools
- Simple-on-screen measurements
- Management of Hyper Index stacks of spatial information

Atlas data and S/W (the interface needs to be also available in different languages including Greek) need to be installed on single-user machines or posted on a "network". This is to be clarified by the End User.

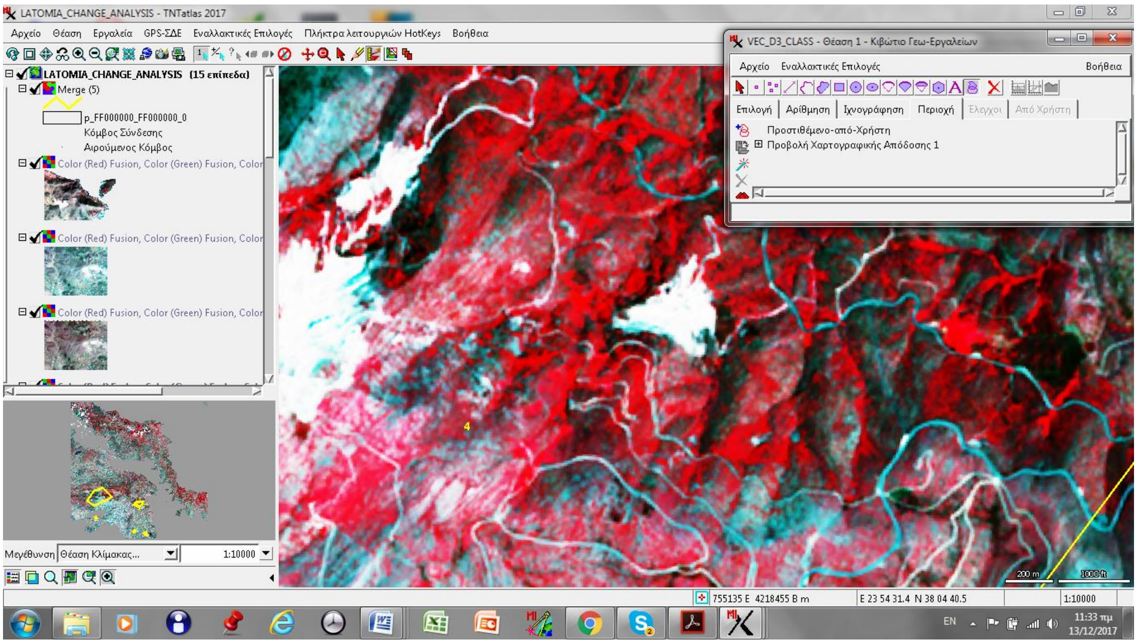


Fig. 1-21 Interface of Atlas data showing results (fifteen different images and thematic layers) of all quarry areas form the processing of multi-temporal Sentinel 2 data.

Description of the Results archived

It is indicated that using the medium and high resolution satellite remote sensing data and integrated image processing and GIS techniques with parallel development of a geospatial database system provided monitoring and feedback at appropriate spatial scales for further use by the End User. The methodology can be used for long-term environmental management, and monitoring of quarry areas along with issues related to reclamation and rehabilitation.

Remote sensing provides valuable information concerning different environmental parameters. Monitoring is supported due to the multi-temporal character of the data. Generally sufficient data required for environmental mapping are not available and therefore, satellite data can be analyzed to generate GIS database information required for environmental studies. Generated database can be used to assess changes that are taking place in the environment. The added advantage of the proposed approach is that it makes available to end-users a variety of the data and that it helps in efficient analysis and the support of the activities of the End User.

New environmental policies require many agencies to provide public access to information gathered with public funds. By virtue of its geographically structured approach, an Atlas offers an intuitive, self-paced, and self-contained way to provide secure public viewing of data such as multi-temporal information provided by satellite systems, census data, land cover / use, and available environmental information. In general the immediate benefits / application of the developed methodology, if it is coupled with high resolution images (up to 1-0.5 meters), to the End User and the mining industry in general are as following:

- Quarry Site mapping - Mapping Disturbed / undisturbed land - Land use / cover changes - Delineation of areas where potential excavations activities are taking place.
- Track changes of the activities which are implemented through the comparison of multi-temporal images.
- Identification and characterization (by the competent Greek authority) of the nature (authorized or unauthorized) of the changes observed - Compliance with permitting regulations.
- Documentation of the conditions of lands related to quarries.
- Reclamation monitoring.
- Discrimination of geologic setting - Geologic feature extraction to optimize field reconnaissance.
- Planning exploration activities - Managing mining activities.
- GIS database creation - Staff and Public relations / visualization.

2. CYPRUS

2.1. Identification of possible study

2.1.1. Name of the pilot site

Amiantos Mine in the Troodos Area

2.1.2. Summary

Cyprus is regarded as one of the most ancient sources of asbestos and until its closure in 1988 was one of the most important producers of chrysotile asbestos in Europe. The asbestos outcrops attracted the interest of people due to its characteristic fibrous texture. In the ancient times, particularly during the Classical and Roman periods, asbestos was used for the manufacturing of shrouds for the cremation of dead, shoes and wicks for lamps. The production of asbestos in an organized scale began at the present site in 1904. Since then and until the mine's closure in 1988, it is estimated that 130 million tons of rock have been excavated, producing one million tons of asbestos fibers. Until 1950, the excavation of the ore was carried out manually, by digging and picking, and consequently it was absolutely dependent on the employment of a large number of workers (several thousands). After 1950, the large-scale mechanization of the mine began with the use of heavy extraction machinery, while from 1963 onwards a 9-story processing plant began to operate.

The mining activity is obviously closely associated with nature. The ore is extracted from the earth; this extraction brings about changes in the landscape and the vegetation of the place. The lengthy operation period of the mine by the open cast method has unavoidable affected the natural environment of the area and had direct and indirect impact to the broader environment.

The main environmental problems that resulted from the mine operation are the vast mine pit, the extensive waste dumps with steep, in places unstable slopes, the complete destruction of the pine forest of the area as well as the pollution (from the presence of the fibers) of the atmosphere and surface waters that drains in dams further downstream. All these changes have possible consequences to the safety and health of the people who reside at nearby villages. Following the termination of the mining activities and the mining lease in 1992, the Cyprus Government undertook the rehabilitation works. The realization of pilot project was very useful for planning and localization of these works.

2.1.3. Description of the pilot site

The Amiantos asbestos mine (Fig. 2-1), closed down in 1988, is located within a Natura 2000 site in the Troodos National Forest Park, at the eastern slopes of Troodos mountains. It is situated in a mining lease covering a surface of 6,5 square kilometers and is of the opencast type, where chrysotile asbestos has been exploited since 1904.

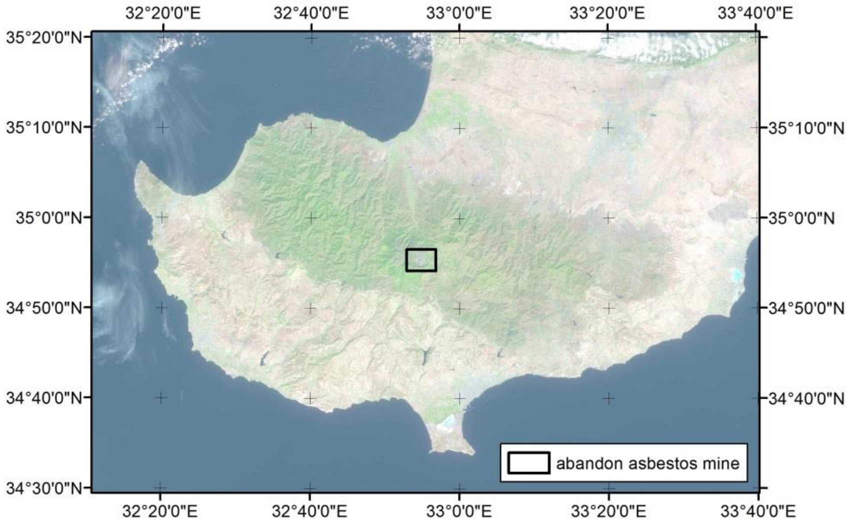


Fig. 2-1 Location of the Amiantos Mine in central Cyprus.

Fig. 2-2 The view of the former mine.

Fig. 2-3 The view of the former mine.

Troodos Ophiolite complex is regarded as the most complete and studied ophiolite in the world. It is a fragment of a fully developed oceanic crust, consisting of plutonic, intrusive and volcanic rocks and chemical sediments. The stratigraphic completeness of the ophiolite makes it unique. It was created during the complex process of oceanic spreading and formation of oceanic crust and was emerged and placed in its present position through complicated tectonic processes relating to the collision of the Eurasian plate to the north and the African plate to the south.

Tectonised harzburgite is the dominant rock type in the Mt. Olympus area (highest peak of Troodos range), where it forms the central core of the Troodos massif. It is always coarse-grained with a xenomorphic granular fabric. Serpentinisation is pervasive throughout the harzburgite mass and ranges from 40% to 100%.

On the eastern side of Mt. Olympus, where the pilot site is located, the harzburgite is totally serpentinised, intensely sheered with abundant chrysotile occurrences, serpentine breccias and breccia zones. Mineralization occurs in veins, which vary in thickness from a few mm up to 1.5 cm. The average grade of the deposit was 0.8-1.0%.

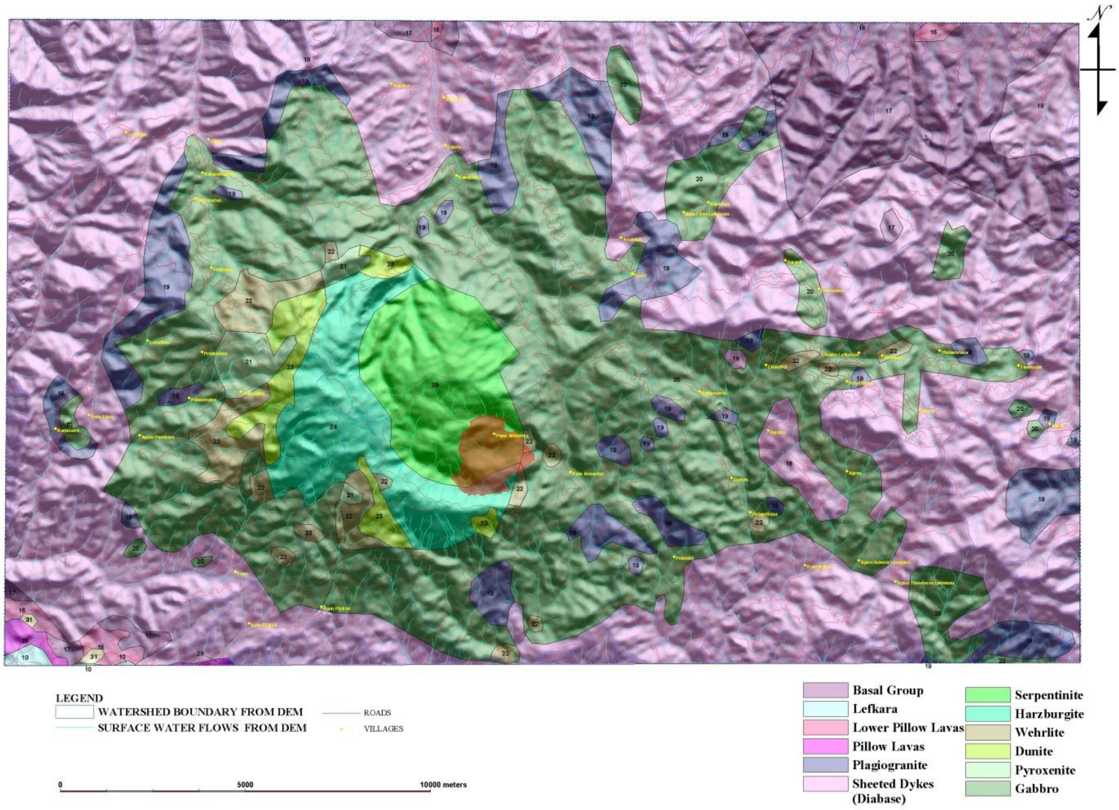


Fig. 2-4 Geological map of the Amiantos Mine.

The asbestos mine pit is bound by Livadhi valley in the North and the Loumata valley in the South and the two valleys meet about 700-800 m downstream of the mine pit. Mining operations in the early part of the 20th century were of a small scale. Selective open cast mining was carried out by a large labour force and the waste material was tipped in the nearby Livadhi valley at the lowermost part of the slopes. In this way substantial amounts were washed downstream thus making room for more wastes. The tip that was formed during the early years of operation of the mine covers an area of some 35 hectares (0.35 Km^2) in plan and the maximum depth of waste is of the order of 25-30 m.

In the early 50´s the mine was fully mechanized and the use of modern mining equipment changed radically the scale and concept of mining operations. The annual production of rock was of the order of 6 million cubic meters, which after crushing, treatment and fiber extraction it was tipped as a waste. These operations resulted in huge volumes of waste material (known as “old tips”) which the steep slopes of the existing dumping areas could not accommodate. In an effort to alleviate the problem, the mining company started to dump the waste material in the nearby Loumata valley. For drainage purposes a 1.3 Km long, concrete gallery was built along the valley bottom and wastes were dumped over the gallery infilling the valley. It is estimated that about 60 million cubic meters of waste were dumped in this valley. When maximum heights of the order of 100 m above the gallery were reached, the culvert itself started to show signs of distress and structural failure. Dumping over the culvert was discontinued and only partial dumping in the side slope was allowed. The waste tips in the Loumata valley are known as the "new tips" and they consist of the lower level tip at elevation 1350 and the upper level tip at elevation 1450 m amsl.

Since 1995 the mine is under restoration and the area is a State Forest Land that later was declared as a Natura 2000 site (Fig. 2-5).

The rehabilitation works have included the following:

- Re-profiling and stabilizing of the waste dumps
- Construction of berms and soil-covering
- Reforestation and revegetation of the berms
- Risk assessment due to the existence of the mine
- Future use of the area

Fig. 2-5 Slope of abandon mine after reforestation (from Kyrou et al., 2005).

The need for reprofiling the slopes of the waste tips was dictated by safety, environmental and other practical reasons. Possible instability of the tip could endanger lives and property in the village of Kato Amiantos which is situated approximately 1 Km downstream of the tips. Thus, the primary aim of the reprofiling works was the stabilization of the waste tips. Furthermore, flow of waste materials downstream of the pits could result in serious contamination of the river water and as a consequence, of the reservoir of Kouris dam, further downstream, which is the main water supply reservoir for domestic and irrigation purposes in the southern part of the island. Environmentally the artificial slopes of the wastes contrasted the natural slopes and the general topography of the neighbouring area. Proper reinstatement of the environment, essentially required some form of reshaping and reprofiling of the slopes to blend with the rest of the environment.

In deciding this issue, it was considered essential that the form of reprofiling would intercept surface water flows thus preventing flow of fibers in the valley streams. Furthermore, in view of the alkaline nature of the wastes, which prevents the grow of any form of vegetation, it became apparent that access to lorries would be essential on the new slopes for the transportation of fertile soil, planting and irrigation. Following consultations with the experts of the Forestry Department it was decided that the maximum slope that would facilitate the grow of vegetation would be 2 horizontal: 1 vertical. In addition, berms 8 m wide at 15 m elevation intervals, would be required for the planting of trees. A typical profile adopted and implemented at the Loumata valley tips. This slope is the highest man-made slope in Cyprus with a total height in excess of 240 m.

Following completion of the stabilization (reprofiling) works at the two main waste tips, it was considered essential to monitor movements both for safety reasons and for better understanding of the geomechanical behaviour of the waste material. In extensive monitoring system that involves the measurement of surface and deep-seated ground movements and water levels, has been installed. The system includes survey monitoring stations and surface movement markers and inclinometers. Movements recorded, indicate that the old tips are prone to small creep type movements which seem to be more pronounced during the wet winter months.

So far 40-50 % of the area of the mine has been rehabilitated. The documentation for the rehabilitation works including and older documents from the time that the mine was still operating.

2.1.4. Description of existing data

For the purposes of the pilot project the Geological Survey, Forestry, and Water Development Departments provided the available geological and mining data either in hard copies (old data) or digital form, in the cases that they were scanned or produced electronically. Geological, topographic and land cover data are available from various sources and in various formats. A geologic map of the area is available in raster and vector formats and it is available by the Geological Survey. Topographic data are available in vector and CAD formats by the geological Survey. Data concerning the reforestation of the area are available by the Forestry Department.

Additionally DEM & land cover data can be obtained by the EU Copernicus service http://land.copernicus.eu/pan-european. The pan-European component is coordinated by the European Environment Agency (EEA) and produces satellite image mosaics, land cover / land use (LC/LU) information in the CORINE Land Cover data, and the High Resolution Layers.

The EU DEM can be downloaded from http://land.copernicus.eu/pan-european/satellite-derived-products/eu-dem/view. And Natura 2000 data can be downloaded from: http://ec.europa.eu/environment/nature/natura2000/index_en.htm

All the data could be classified and described in three main categories:

- Geological and mining data, maps, documents,
- Remotely sensed data,
- Monitoring data.

Description of existing datasets, maps, documents, geological and mining data.

The Department of Geological Survey has provided the most geological and mining data, such as documentation, expert assessments, stability reports, measurements data and maps for the asbestos mine area. Quite a number of these materials have been focused mainly on displacement and stability issues of the excavation site and its surrounding. Selected papers are presented and briefly described below.

Preliminary report on the ore grade and pit slope stability of the Amiantos mine, Dec 1980 – the report describes an evaluation of the general nature of mineralization and the consequent implications to mining practice, and to make an initial appraisal of the slope stability problems encountered in the pit.

Initial geotechnical assessment of Amiantos mine, Jun 1981 – the questions of open pit and waste tip stability are discussed together with stabilization techniques to improve potentially unstable areas. Also, the problem of declining yield has been accompanied by the continuing instability of the southwest pit wall.

Report and addendum to reconnaissance of tip stability, Jul 1982 – identifies the most important instability problem area to be the slope downhill of the Old Mill with the nearby tip complexes. Special attention was paid to the position of the village of Pano *Amiantos*, which is situated downstream from the mine workings and old waste tips and is in particular danger area of a landslide.

Old waste tip stabilization, Investigation and Design Report, Nov 1984 – final report that undertakes the investigation and design of the slope stabilizing works required for the old waste tip. This report also presents findings and includes construction drawings for the recommended remedial works.

A summary of preliminary geotechnical investigation, Feb 2016 – this study is focused on instability problems observed in the area of the old Asbestos Mine. These instabilities are related to cracks and subsidence both in the area of the two lakes and in the area of the terraces which are situated at the east of the reservoirs. Additional instabilities were also found in place, which seem to follow the old, underground rainwater pipeline. All instability points which were identified can be seen on the map.

Fig. 2-6 Map with locations of instability points.

The Forest Department has provided maps and cross sections of areas for restoration and reforestation. Both maps and cross sections are in Greek and in digital form, saved in vector CAD format (files with *.dwg* extensions). We have also received shapefiles (*.shp* extension) with segments (polygons) affected by reforestation tasks in the years 1993-2015.

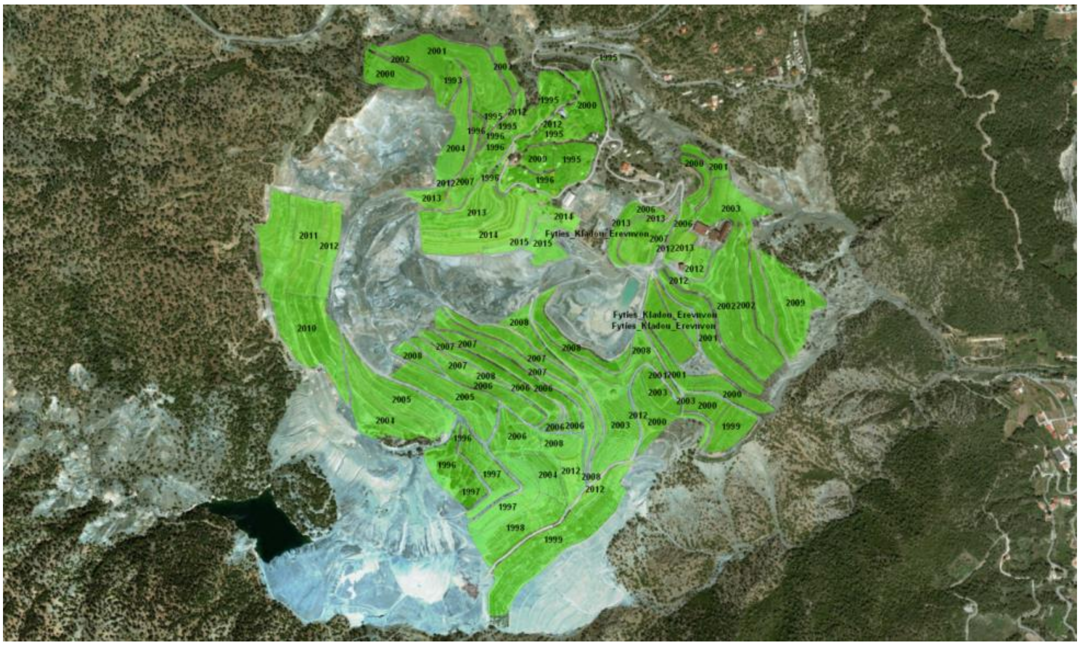


Fig. 2-7 Areas (transparent green polygons) affected by reforestation tasks in the asbestos mine in the years 1993-2015.

Water Development Department has provided documents, study, and maps for hydrogeological conditions of the pilot site. There is a full study in Greek from Nov 2016 about stormwater management for the catchment area of the new pond in the crater of the Amiantos mine. The main purpose of the study is to upgrade and optimize the stormwater management system and develop a rainfall-runoff model of the drainage area of the lake to simulate the operation of the whole system and examine various alternative scenarios.

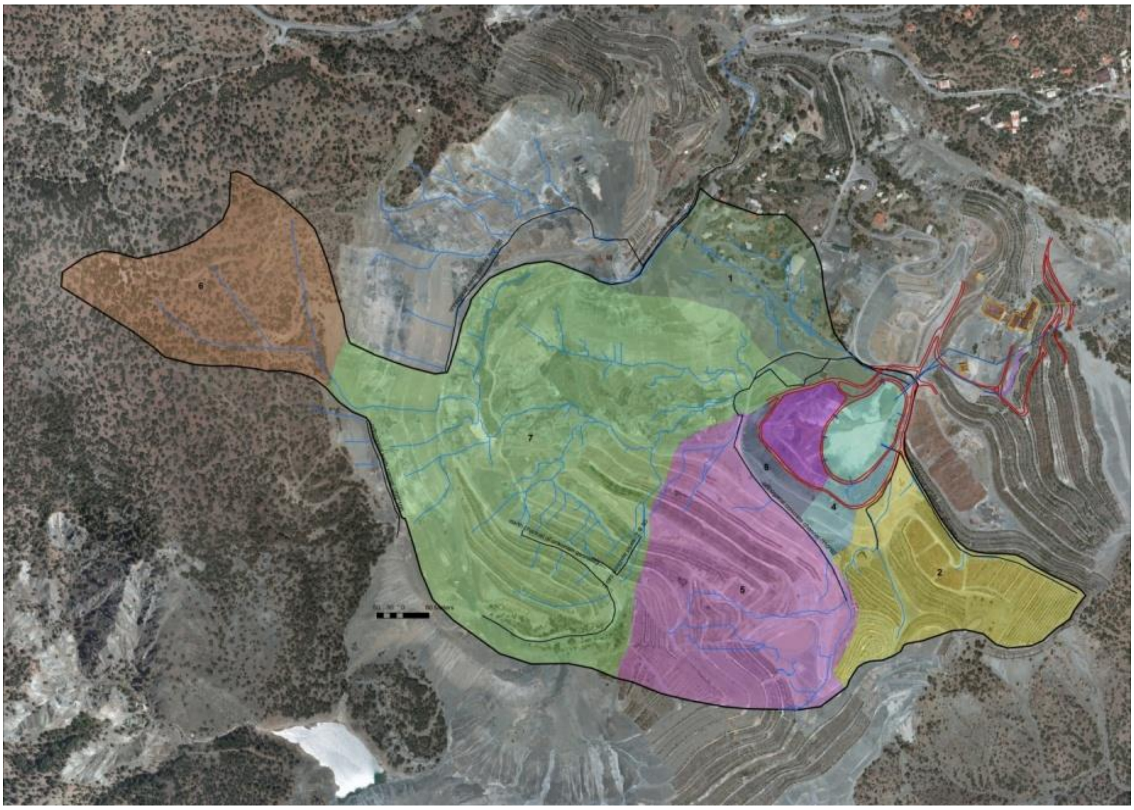


Fig. 2-8 Map of water subcatchments and drainage.

Moreover, we have received several maps showing hydrological phenomena, conditions, and models for example map of water flow direction, a map of existing drainage network, a map of water subcatchments, a map of new survey contours and DTM. Some of the older maps have been scanned or digitalized, while the new ones are in digital form (*.jpg*, *.tiff*, *.dwg*).

The CORINE Land Cover is provided for 1990, 2000, 2006 and 2012. This vector-based dataset includes 44 land cover and land use classes. The time-series also includes a land-change layer, highlighting changes in land cover and land-use. The high-resolution layers (HRL) are raster-based datasets which provides information about different land cover characteristics and is complementary to land-cover mapping (e.g. CORINE) datasets.

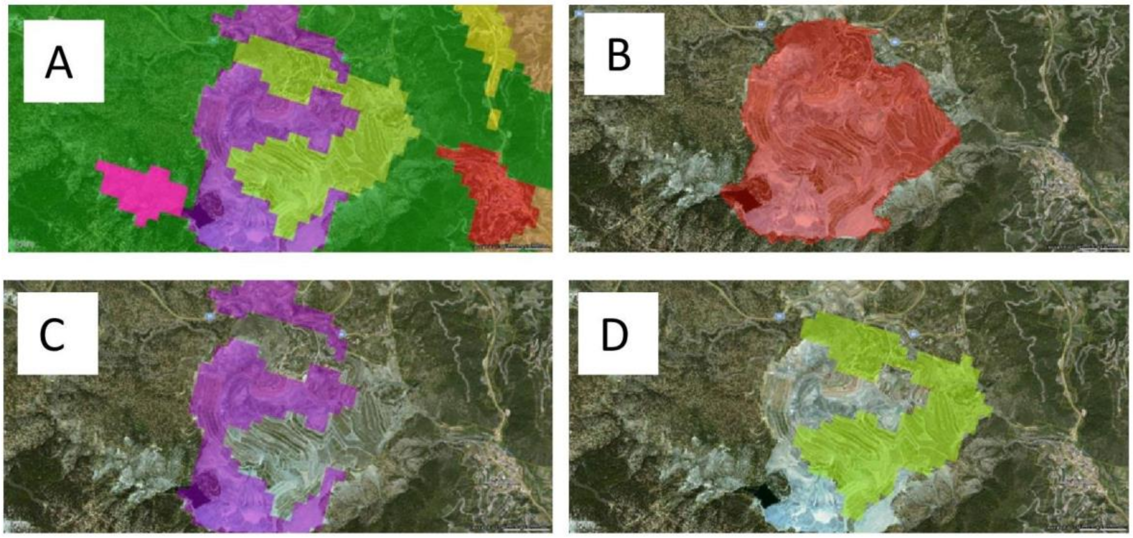


Fig. 2-9 Corine land cover LC/LU of the Asbestos mine (A) / Polygon of the mine as identified by the End User (B) / Mining area according to LC/LU (C) / Reforestated area according to LC/LU (D)

It is shown that the mapping scale of LC/LU is coarse for monitoring the mining area as just two classes have been identified for the whole of the mine.

Description of existing remotely sensed data.

As far as existing remote sensing data for the area of interest is concerned, only aerial and space-based optical images are available. Both datasets of images depict the village of Amiantos and its surrounding, where former asbestos mine was located. The oldest set of aerial photographs were obtained on 14 November 1967, back in times, when the mine was still operational.

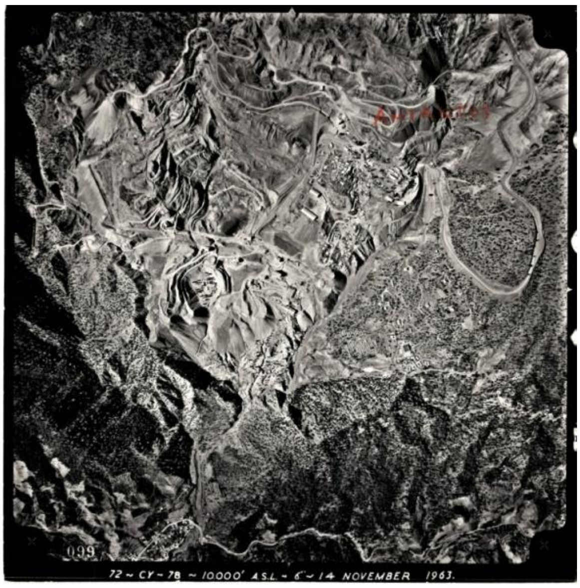


Fig. 2-10 Aerial photograph showing the asbestos mine in 1967.

All of the air photos were obtained from the altitude of 10 000 feet above sea level, which is approximately 3 kilometers. The size of the frame is 23 x 23 centimeters. The dataset of the aerial images contains 23 scanned aerial photographs in digital form saved into one pdf file.

Taking into account satellite data, we have at our disposal imagery obtained from three different sensors: Corona, ASTER, and QuickBird.

The oldest space-based optical images were obtained during Corona program, which involved a series of American strategic reconnaissance satellites, operating in 1959-1972. Corona dataset contains three panchromatic images, that were captured from KH-4A (*'Key Hole'*) satellite, operational in the time period of Aug 1963 – Oct 1969. Two of the three images were obtained in 1968 during a part of a mission no. 1046 and represent one stereoscopic image. The third stand-alone image was taken in 1967 as a part of mission no. 1042. The imagery was acquired from the mission orbit set at 75 miles (121 kilometers) above the surface of the Earth with the approximate resolution of 3.0 meters.

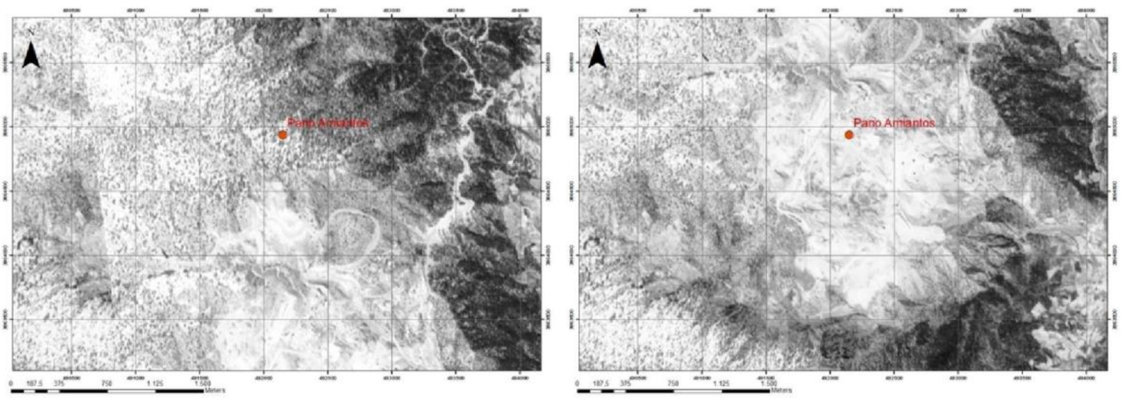


Fig. 2-11 Left and right panchromatic image of stereo pair acquired from KH-4A satellite in 1968.

Second in the timeline comes images from ASTER (*Advanced Spaceborne Thermal Emission and Reflection Radiometer*), which is a Japanese sensor on board of the Terra satellite that was launched into Earth orbit in 1999 and has been collecting data since Feb 2000. Aster provides images in 14 different bands of the electromagnetic spectrum, ranging from visible to thermal infrared light. The images are acquired from orbit set at 705 km and their resolution ranges between 15 and 90 meters. For the purpose of the pilot project, we were provided with one ASTER image.

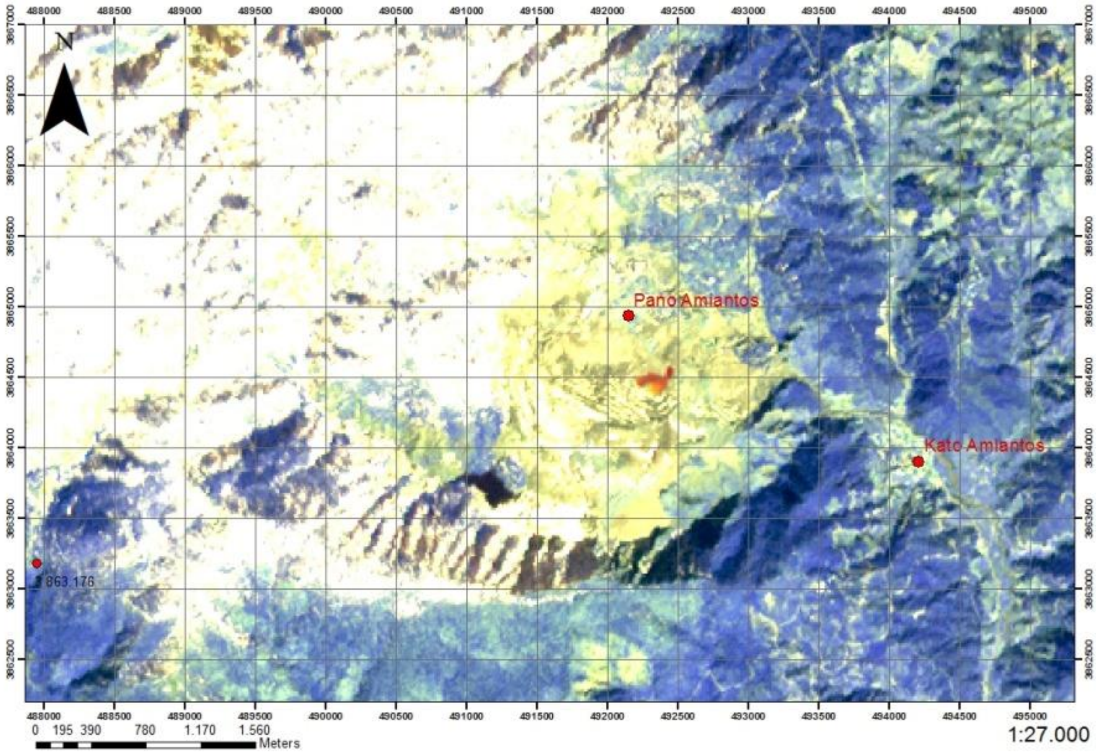


Fig. 2-12 Space imagery showing the asbestos mine in Amiantos and surroundings, obtained by ASTER sensor.

The most recent satellite imagery comes from QuickBird satellite. QuickBird dataset contains three images, each acquired in a different composition and time period. The first image was obtained in 2003 in panchromatic, the second one in 2008 in visible RGB, and the last one in 2010 in NIR (near infrared) composition. The satellite collected panchromatic imagery at a 61-centimeter resolution and multispectral imagery at approximately 2.44 meter for the original orbit altitude of 450 km.

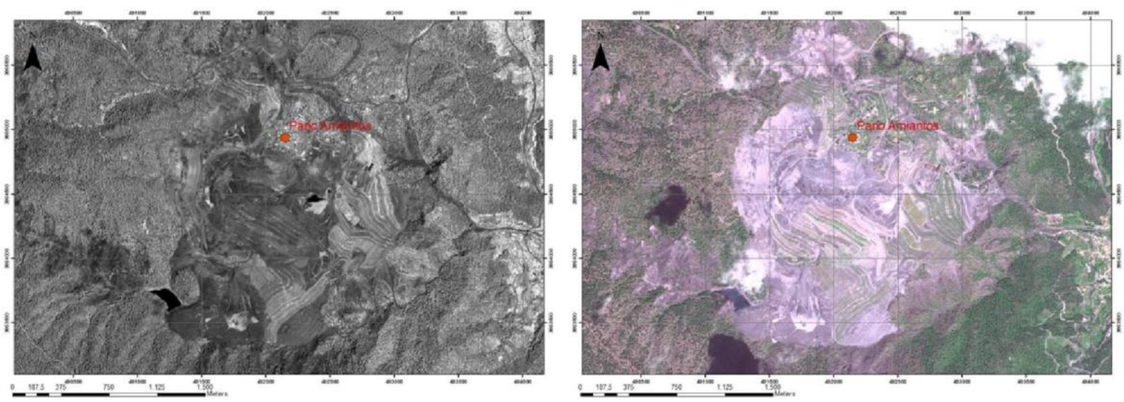


Fig. 2-13 Panchromatic (left) and visible RGB (right) composition imagery from QuickBird satellite.

All of the space-based optical images datasets is in digital form saved into separate jpg files.

Earth observation data like Aerial photography dated in 1963, CORONA images for the period of 1060 to 1970, ASTER image and Quick Bird satellite data for the years 2003, 2008 and 2010 are available in the Geological Survey of Cyprus. However these data are not regularly updated while they have different configurations. It is indicated that satellite data are needed in order to establish an up to date monitoring system for the Asbestos mine. Sentinel 2 satellite system has been selected to be evaluated for “monitoring the mine”.

Sentinel 2 data can be used for monitoring local processes as its specifications are comparable but with enhanced features in relation to other satellite systems like the Landsat series. The data are freely available to the scientific community.

Another type of data is the Ortho-photos provided within TNTgis S/W like Bing maps, Fig. 2-14.

Fig. 2-14 Bing maps ortho-photo integrated within the GIS system - Google Earth can also be synchronized as an external viewer in the GIS system.

Information on possible access to monitoring data.

Information on possible access to previous (present) monitoring data (geodetic, hydrogeological, geochemistry, etc.):

In the locations of the rehabilitated areas that there are ground indications such as instabilities or subsidence, the Geological Survey Department has installed inclinometer casings for monitoring. Since February 2016 an inclinometer system is under operation in the Asbestos mine and Cyprus Geological Survey Department provided a full report on inclinometer readings in the periods from March 2016 to June 2016 and from September 2016 to April 2017.

In the past, slope and tip stability were under surveillance by regular inspection tours and possible photogrammetric techniques. All the available results could be provided for the needs of the pilot project.

In case of hydrogeological monitoring, piezometer installation has been made and it is suggested that these are read on a fortnightly basis and following heavy rainfall. In addition, on completion of each borehole down to the required depth, a standpipe piezometer was installed for monitoring of groundwater levels.

In case of geochemistry monitoring, laboratory testing on disturbed samples of soil and chemical analysis of water recovered from boreholes and streams on the face of the slope were carried out.

2.2. Project description

2.2.1. Objectives and expected results

One of the major outstanding environmental problems related to mining is that of abandoned mine sites, a legacy of centuries old practices, of inadequate, insufficient or non-existent mine closure plans. The potential costs of rehabilitation, the lack of clearly assigned or assumed responsibility, the absence of criteria and standards of rehabilitation as well as other factors have delayed action by all parties – industry, governments and communities. Yet, land degradation from old mine operations is well known in almost all countries. While derelict sites are extensively referred in the literature, there have been few systematic surveys to quantify how many sites need attention. There has been even less work to quantify the nature of associated problems so as to prioritize remediation efforts. The impact of mining sites is significant concerning environmental and safety problems including: altered landscape; unused pits and shafts; land no longer useable due to loss of soil, pH, or slope of land; abandoned tailings dumps and dams; changes in groundwater regime; contaminated soils; subsidence; and changes in vegetation. Results of such impacts include: loss of productive land; loss or degradation of groundwater; pollution of surface water by sediment or salts; changes in river regimes; risks of falls into shafts and pits; and landslides. The resulted delineated waste materials areas advance the knowledge on the critical hazardous areas for remediation purposes. The proposed roadmap promotes specifications and methodologies for engaging future operations fitted to raw materials demand, minimising the environmental footprint, and improving the evaluation of the sustainability and management of the post-mining areas.

In the case of Cyprus 32 out of 33 mines are abandon. The chosen Asbestos mine located in central part of Troodos Ophiolite is one of the examples. As a result of constant operation works between 1904 and 1988, the mine had significant effect on the surrounding environment, including enormous open pit, extensive waste tips, pollution of the soil and water, unstable slopes of the abandon structure and waste tips and the barren nature of the tips. Therefore, the proposed activities were chosen with the aim to define the roadmap for long-term monitoring, mapping, and management of the rehabilitation works, also assessing the ground changes and site degradation relating to mineral exploitation.

The end user need were defined as follows:

The Geological Survey Department is responsible to evaluate the situation of each abandoned mine in terms of a) potential source for secondary mineral resources, b) actual sources of environmental pollution and c) to propose and implement remediation measures for the benefit of the affected communities. Even though there are a lot of in-situ data, they never hold or used any space born data for the active or abandoned mines. The opportunity to obtain and use space born data will help develop the necessary skills in order to plan and execute more comprehensive and effective solutions / measures for a) long term monitoring of ground deformation /stability waste dumps, b) map waste dumps and abandoned mines as potential exploitation for both primary and secondary mineral resources with parallel environmental restoration and c) develop better practices for the rehabilitation of abandoned mines.

Through the usage of space born data and in-situ data that holds the Geological Survey we expect to evaluate the stability of the rehabilitation works at the asbestos mine that were carried out so far and any environmental pollution in the surrounding area. If any instabilities are identified, they shall be faced to prevent any landslides or other instabilities and take into account the findings and incorporate them in the ongoing and future rehabilitation works.

The space born data could be also used to assess the existing field data and develop a protocol for the restoration and closure of the mine preventing any environmental pollution of the surrounding area.

Specific main objectives of the Asbestos Mine pilot feasibility study are as follow:

- Determination of ground stability of the former mining area, taking under special consideration the slope mass movements and vertical ground motions.

- Determination of the land use changes and monitoring progress of restoration works.
- Identification of the local pollution (if possible) related to former mining activities.

2.2.2. Methodology, methods of implementation

The general plan of the pilot study includes 3 separate tasks.

1. Determination of the ground stability

The task was performed using satellite interferometry method.

Space-borne differential synthetic aperture radar interferometry (DInSAR, Ferretti et al., 2007), and in particular new advanced processing techniques such as Permanent Scatterer Interferometry (PSInSAR or PSI, Ferretti et al., 2001), offer a unique possibility for wide-area, regular monitoring of ground surface displacements. Furthermore, under suitable conditions it should be possible to detect precursory deformations associated with the initiation of ground instability, a key element for early warning and hazard mitigation (Ferretti et al., 2001).

It is a technique in which the phase component of a return radar signal from two or more satellite radar images (of the same location) is processed to detect motion on the ground. The relatively low cost of the method (one radar photo covers an area of about 10,000 km^2) and non-invasive nature have led to its wide application in various disciplines. One of the priority disciplines is geohazards, related to land surface displacements caused by natural factors, human activities, or the combined effect of these two. DInSAR method has been implemented since 1992, shortly after the launch of the ERS-1 satellite equipped with the SAR (Synthetic Aperture Radar) radar imaging device. With its help on the analysis of interference bands, seismic phenomena volcanic activity, landslide and subsidence and other phenomena that have a direct impact on economic, environmental and human safety are identified. The need for more precise and reproducible data has led to the development of this technology over the past few years, including the development of a Persistent Scatters Interferometry (PSInSAR) algorithms.

Unlike conventional radar interferometry (DInSAR), PSInSAR method consists in processing of a very large amount of data (the number of radar scenes must be greater than 15). As a result remain only these pixels that have high coherence within whole set of scenes which allow to identify continuous measurement points - PS (permanent scatterer). They are usually buildings, bridges, outcrops rocks, etc. The characteristics of the movement of these objects are recorded and calculated with a millimeter accuracy throughout the period covered by the satellite data.

The method was initiated in Italy in 2001 (Ferretti et al., 2001). Since that time over dozen different PSI algorithms were developed differing in approach in the processing and identification of PS points (Crosetto et al., 2015). The newer one, SqueeSAR (Ferretii et al., 2011) algorithm is now being improved and implemented by many InSAR institutions, as it allows for the identification of significantly more measurement points.

PSInSAR is a unique technology that is able to perform both annual and multi-year measurements for each individual measuring point - PS. For each PS the coefficient of coherence is determined (values are from 0 to 1). The higher the coherence coefficient, the more reliable the point is and the less signal distortion (errors due to the ionosphere and orbit). PS with coherence coefficient less than 0.6 are considered uncertain and discarded. It is also assumed that in the so-called PSInSAR time series, the displacement rate is calculated only on the basis of points having the highest confidence level, i.e., for which the coefficient of coherence is equal to or greater than 0.9. Low coherence values are usually acquired on the pixels corresponding to vegetation cover and high land cover changes through acquisition period (e.g. snow). High coherence is usually obtain on the urbanized areas.

PSInSAR uses a linear displacement model (assuming that the surface movements are continuous and characterized by a steady rate in the time period) for measurement points. Not rapid nonlinear displacements can also be identified using a linear displacement model. For each identified PS a time series of the movement can be obtain, allowing visual interpretation of the movement trend over time.

Undoubtedly, the disadvantage of the PSInSAR technique is the difficulty in predicting the quantity and location of PS before processing. As a rule, the positive effects are partially guaranteed in urbanized areas, dry climate areas and rocky areas. Furthermore satellite PSI data have to be reference to well ground truth measurements, because they reflect performance of targets, whose actual or apparent displacements may arise from a variety of causes (e.g. slope movements, fill settlement, subsurface civil engineering, mining and fluid extraction, differential movements between cut and fill parts of a building site, structure deterioration, expansion/shrinkage of soils). Also, it is worth remembering that it is a remote sensing technique and therefore measured PS point does not always can corresponds to the benchmark on the ground, measured by traditional geodetic measurements.

2. Determination of the land use changes

Environmental monitoring is now an integral part of mining operations. Remote sensing enables the identification, delineation, and monitoring of mining areas, including derelict land, and changes in surface land use, (Charou E. et al., 2010, Vasileiou E. et al., 2012). The aim of this pilot site is to evaluate the use of Earth Observation and in particular of the multi-temporal Sentinel 2 data to map and monitor the Asbestos mine on a local scale, and to assess the rehabilitation activities by indicating the changes on land. The general plan of the methodology applied for this Pilot Site is shown in Fig. 2-15 and it includes:

- Mapping and monitoring (Change analysis / track any detectable potential changes of surface morphology) based on satellite Sentinel-2 data.
- Identification and evaluation of rehabilitation activities which are to be archived by developing a Monitoring System (Tool) with the use of EO data.
- Evaluation of the contribution of Earth Observation data on supporting studies of mapping and monitoring of abandoned mines. Fig. 2-15 shows the overall plan of the Sentinel 2 monitoring system of the Asbestos pilot project area.

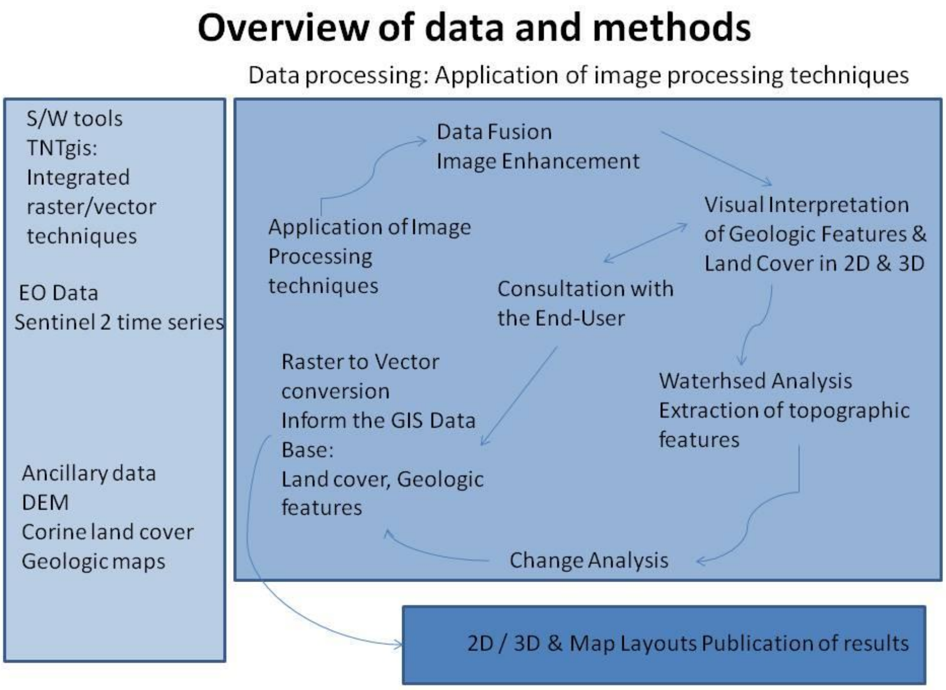


Fig. 2-15 Overview of overall plan of "Data and Processing techniques" applied in the abandoned mine in Cyprus

Initial processing for change analysis and monitoring is based mainly on satellite Sentinel-2 data using time series data for the period of 2015 to 2017 for the pilot project area.

The basic S/W tool used for the integrated analysis of both raster and vector data is the TNTgis software. Research has been accomplished following step by step analysis including (1) Pre-processing of EO data, (2) Image processing, (3) Application of classification techniques, (4) Application of GIS techniques, (5) Evaluation of techniques for the distribution of processed information.

Consultation with the End User has been carried out so as to identify its needs. The feedback gained during the consultation has been integrated in the various stages of analysis so as the analysis of the Earth Observation data to cover User's Needs.

3. Identification of the potential pollution sources

Remote sensing methods are very useful for monitor pollution from mining at less cost and to common standards across the EU. Faced with increasing environmental pressure and regulatory controls due to surface and groundwater pollution, soil contamination. The mining industry and decision makers need innovative and cost-effective tools for environmental data acquisition and processing that provide basis for sustainable economic development of the sector. These tools can help in decision-making process. EO methods could potentially be used in future sustainable information systems that locate and monitor environmental risks. Regularly updated information stored in databases related to mining environments is used to draw up Environmental Management Plans (EMPs). To collect this information innovative earth observation techniques should be used. Existing Hyperspectral imaging sensors and multispectral satellite images of new generation which identify and map materials through spectroscopic remote sensing produce data that can characterize the chemical and/or mineralogical composition of the ground surface. The primary advantages of this future space-borne imaging technique are the reduction unconventional, time consuming and expensive field sampling methods and its capability to gather repeat data, which assists in monitoring mining pollution.

2.2.3. Main activities

1. Determination of ground stability of the former mining area, taking under special consideration the slope mass movements and vertical ground motions.

In the first stage it is proposed to carry out the analysis of historical satellite data (1991 - 2012). The analysis should include data from ERS - 1, ERS - 2 and ENVISAT satellites, which should be processed using the PSInSAR algorithm. A better option would be to process data using the SqueeSAR methodology. Forest areas or dense vegetation are predominant in the study area, which can make it difficult to obtain reliable results. The SqueeSAR method should therefore guarantee a much better result.

Obtained PS data should be statistically elaborated according to standard procedures (time series, density analysis, geostatics interpolation, etc.). The above data should also be analyzed and compared with (if possible):
- Traditional ground geodetic measurements (precision leveling).
- Data from permanent GPS stations.
- Digital terrain model (DTM).
- Land use maps.
- Geologic maps.

Based on the analysis of the above data, a background map of the surface displacement rate should be developed.

The classic DInSAR method and the PSInSAR method are mainly used to analyze the mobility of large areas. In the case of monitoring of objects of special importance or where there is a dense vegetation cover, a network of artificial ground-based corner-reflectors (CR-INSAR) is also used (e.g. Perski et al., 2017). Artificial reflectors should be designed and installed so as to be visible by both ascending and descending satellites tracks. This will increase the precision of the measurements and determine the displacement vectors in both horizontal and vertical plane.

The use of CR-INSAR technology will allow:
• Achieving greater precision in displacement measurements,
• Obtain information about movements in areas where there is a high likelihood of loss of radar signal (e.g. forest areas),
• Precise correlation of InSAR measurements with levelling and GNSS.

Artificial corner-reflectors should be at least 6 so that they are situated on slopes of the closed mine area. They should be installed in exposed areas (visibility of the horizon > 5^{o}) and protected against theft or damage. The next step is to precisely determine the coordinates of the artificial reflector using the GNSS receiver.

In the third stage, the PSInSAR satellite data analysis should be again performed, this time with the Sentinel-1 satellite for 2014-2017 period. Because the area is difficult in terms of InSAR processing, it is recommended to use also high-resolution commercial data analysis such as TerraSAR-X (or similar). Then comparison with the results of the analysis with the ground surface displacement map obtained from the historical data should be performed. The results of the new analyzes should also be verified with respect to ground-based artificial reflectors.

The final product should be the map of the displacement values of the points identified on the slopes of the abandon mine area and its vicinity as well as time-series graphs. The final values should have been previously validated based on ground-truth data. In the next stages of monitoring, a similar analysis should be carried out for the following chosen time periods.

2. Determination of the land use changes and monitoring progress of restoration works

Various image processing and vector GIS techniques are used for the analysis of the satellite imagery and the collected map data.

Pre-processing

Identification of areas of interest with respect to mining area as this has been identified by the End User. Acquisition of multi-temporal data has been carried out for the area for the years 2015, 2016 and 2017. Application of atmospheric correction techniques.

Resampling was carried out using the bi-cubic method.

Image Processing

Colour composites: Various pseudo-colour composites like the RGB-843 have been used of the Sentinel 2 data in order to emphasize the quarry areas, which have high spectral reflectance. The composites accentuated the quarry areas and discriminated vegetation from barren soil.

Decorrelation stretch

Intensity hue saturation (IHS) images: different resolution data were combined using data fusion techniques. This was effective for the land cover and the interpretation of geologic features because complementary information for the same target area was combined. The IHS transform was used to fuse the bands of higher panchromatic spatial resolution with the multispectral bands of the Sentinel 2 so that the inherent land cover classes in the quarry areas could be identified. PCA has been applied of the bands with higher resolution for data noise reduction, while PC1 component has been used as the panchromatic image -PAN in the data fusion process. Final image products derived from this procedure was the 8,4,3-PAN and similar RGB-PAN composites.

NDVI calculation for vegetation and masking

Map layouts in 2D or 3D formats and as Stereoscopic images using the available Digital elevation Model of Copernicus.

Classification

Image Classification Unsupervised classification techniques using neural networks: Artificial Neural Networks (ANNs) are generally quite effective for the classification of remotely sensed data (Vassilas and Charou 1999). For classification purposes, the SOM- Self Organizing Map ANN method was used on the Sentinel 2 images in order to discriminate all inherent land cover classes of the satellite images. Different land cover types were mapped in the quarry areas and the surface extent for each cover type was estimated.

Automated combination of the classification result of multi-temporal imagery: Automated conversion of raster to vector data: the raster output of the classification and/or interpretation process was converted to vector data and these data were analyzed with the corresponding map data and observation acquired on the Ortho-photos (Fig. 2-15).

Processing and analysis: further processing and analysis was performed to derive information concerning changes identified in pilot study areas.

GIS techniques

Collection, input, coding, storage, management, retrieval of various data: all ancillary data (raster, vector, ASCII) selected in this study are aggregated in the GIS in order to assess rehabilitation activities. Extraction of the topographic variables (shading relief, slope & aspect) and Watershed analysis have also applied.

Dissemination of information

It is anticipated that there is a need to disseminate information of collected and processed Earth Observation and GIS data using electronic means (free software) which are to be dedicated to cover the End User needs. This need is further enhanced as processed data have to be delivered in full spatial / spectral and temporal resolution.

3. Identification of the potential pollution sources

The term asbestos is used for certain groups of minerals that have a fibrous form with a length to diameter ratio of at least 100: 1. This name does not mean a specific mineral, but refers to the silicate minerals that make up the fibers.

Typical minerals belonging to the asbestos group includes serpentine asbestos (chrysotile) and amphibole (actinolite, anthophyllite, amosite, crocidoite) and silicate minerals, e.g. diopside, sillimanite, aegirine, lamprophyllite or astrophyllite. A characteristic feature of asbestos occurring in nature is their high tensile strength, flexibility and resistance to chemical and physical factors. In the production process, these minerals can be separated into elastic fibrils, long and very thin. Physical and chemical properties of minerals known as asbestos cause their environmental impact to be quite specific and limited to the harmful effects of very thin fibers with a thickness below 0.01 µm, which are able to penetrate into the lower respiratory tract and dig into the lungs. There remain for a very long time (they are practically non-removable), and cause cancer diseases as a result of many years of cell irritation. The first mention of the negative impact of asbestos on human health comes from 1899 (Tweedale G., Hansen P., 1988). French research from 1910 clearly confirmed the harmful effect of asbestos on the human body, but legal regulations concerning the control of dust in mines exploiting asbestos appeared in the US only in 1971 (Cudgell D.W., Kamp D.W., 2004). At the end of the 20th century, in many countries of Western Europe and North America, a program was created to remove asbestos and products that contain it. Production and import of asbestos-containing products have been banned. In Poland, such a regulation was introduced in 1997. This also applies to the asbestic tile, which is the basic component of roofing materials. This has resulted in a rapid decrease in asbestos demand and production, as a result of the closure of most asbestos mines. As a result, many countries started reclamation asbestos mines and landfill mining waste generated during the operation. Due to the fact that the negative impact of asbestos is primarily attributable to fibers transported by air, the basic reclamation operation, apart from the geotechnical stabilization of slopes, is preventing the process of extracting these particles from reclaimed mining excavations

and waste landfills. This is achieved by sealing the soil surface of excavations and Waste landfills and implementation of vegetation (grass, trees, shrubs). It should be emphasized, however, that geochemical conditions prevailing on post-mining excavations and Waste dumps are extremely unfavorable for the development of vegetation. This is influenced by the features inseparably connected with outcrops of rocks built from basic alkaline rocks: high pH and very low nutrient content, necessary for the development of plant vegetation (N, P, K) (Ellery A.S., Walker B.H., 1986). In addition, reclaimed sites after asbestos exploitation should be excluded from human activities, which can lead to the destruction of the surface, which could enable the erosion of the surface layer, and consequently the emission of fibrils to the atmosphere by exhausting (Shemang E.M. et al. 2014). Asbestos fibers can also be washed out by rainwater and introduced into the river network. As a result, they can be transported over long distances. Taking into account all the above conditions, environmental monitoring of the reclaimed areas after the exploitation of asbestos and post-mining waste disposal essentially includes the following elements of the natural environment:
- air monitoring for the presence of asbestos fibers,
- surface water monitoring for the presence of asbestos fibers and for the content of heavy metals;

Additionally, it may also be conducted:
- monitoring of groundwater for heavy metal content,
- monitoring of water sediments on the content of asbestos fibers.

Investigations of asbestos fibers taken from the air or found in water or water sediments are usually carried out using a scanning electron microscope (SEM).

2.2.4. Results of the pilot site analysis

1. Example processing of Seninel-1 data for determination of ground stability.

For the sample processing of InSAR data a set of Seninel-1 satellite scenes was used covering period from 26 July 2016 to 09 July 2017. The processing was preceded with the basic analysis of possible PSInSAR data acquisition.

a) The analysis of the SAR data acquisition. The analysis was done using Seninel-1 Data Hub (https://scihub.copernicus.eu/) viewer. Cyprus has very good covered of both SAR geometries: ascending and descending (Fig. 2-16). The abandon asbestos mine is in the central part of Cyprus. For the ascending geometry it seems that the processing should include data from two frames to ensure full coverage. For the descending geometry however, the one frame covers nearly whole island. Data acquisition ensure new scene each 6 days.

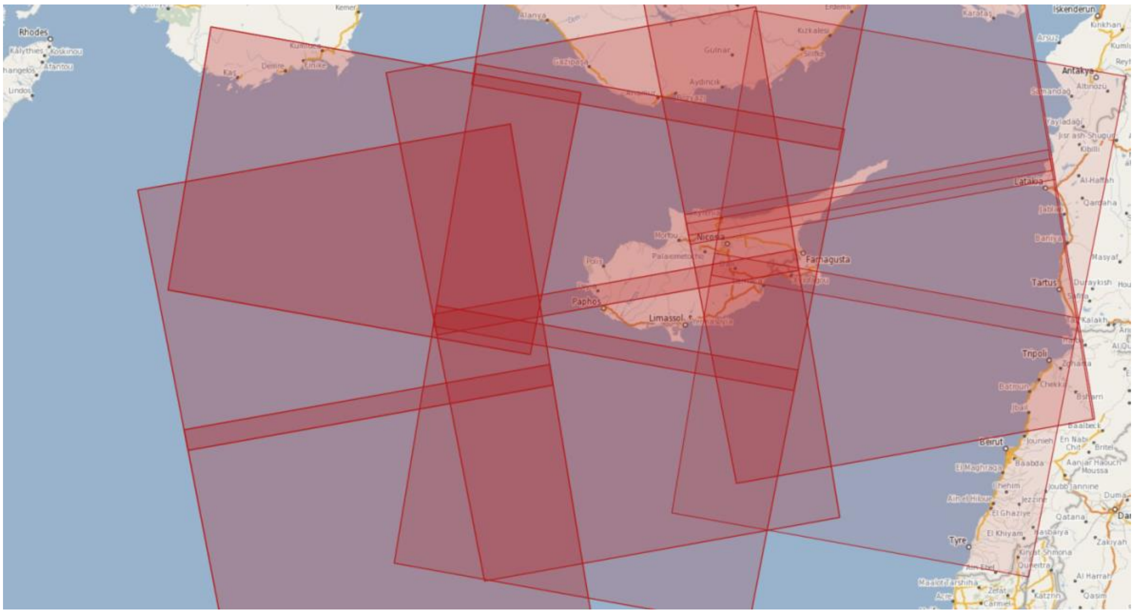


Fig. 2-16 Sample coverage with Sentinel-1 data from https://scihub.copernicus.eu/dhus/#/home. Data frames facing direction NNW-SSE are ascending geometry. Data frames facing direction SSW-NNE are descending direction.

b) The analysis of land coverage and elevation model. Land cover has a significant impact on the results of the processing. PS points are created in pixels with objects strongly and stable in time reflecting the radar wave. These are mainly buildings, roofs, railways, roads, bridges and other metal objects, but also outcrops of rocks. In forest areas or vegetation cover, PS points are difficult to identify due to the absorption of radar waves and the variability of coverage over time.

   The analysis was done visually on the Landsat images, Corine Land Cover GIS layer (Büttner at al., 2013). Additionally digital elevation model SRTM (Rodriguez et al., 2006) was downloaded (Fig. 2-17). Abandon mine is located in the central part of the mountain chain. Surroundings of the mine area are characterized by a large altitude changes and forest cover. In the nearest vicinity of the mine there are no urban or urbanized objects. This makes the terrain difficult for interferometric analyzes, especially when using the C-band radar (ERS, Envisat and Seninel-1 scenes). It would be advisable to use L-band radar scenes with a wavelength of 23 cm. The radar L-band penetrates the vegetation much better than the C band, but such scenes are not freely available.

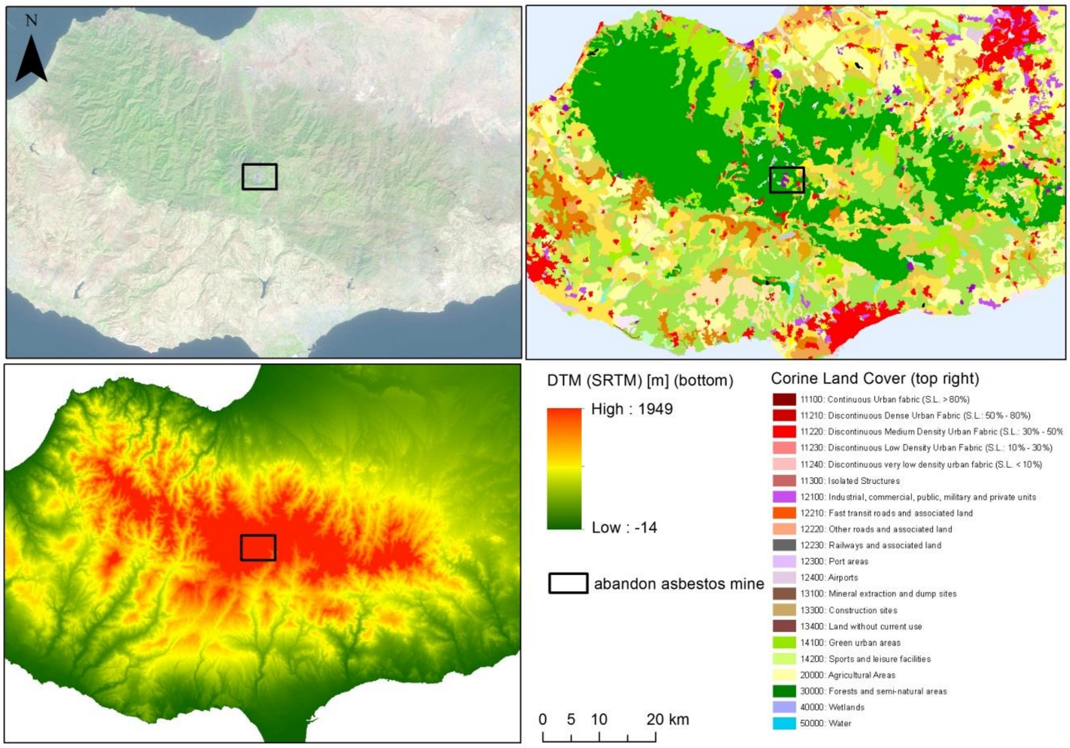


Fig. 2-17 (top left) natural color satellite image. (top right) Corine Land cover GIS layer. (bottom) SRTM DTM. In black square the abandon asbestos mine area.

c) PS visibility analysis. Altitude differences are the basis for checking which satellite geometry will be best for these particular area. The data are collected at the angle, not in the vertical direction. This affects the visibility of terrain pixels, especially in mountain areas. Some areas are obscured from the satellite point of view by adjacent slopes. The visibility of the terrain pixels can be calculated based on the geometry parameters, that can be obtain from metadata of the scenes (Notti et al., 2011, Cigna et al., 2012, Vecchiotti et al., 2017).
For the visibility analysis the following equation was used:

$$R_{index} = -\sin(Slope * \sin(Aspect + \alpha - \gamma))$$

Where:
R_{index} – is the visibility index, values are between -1 and 1, where 1 corresponds to very good visibility.
Slope – slope of the digital elevation model
Aspect – aspect of the digital elevation model
α – heading angle of the satellite
γ - incidence angle of the satellite data acquisition

The results for Sentinel-1, Envisat, ERS are presented in Fig. 2-18. The geometries for these three satellites are similar, therefore, the results show almost the same picture. It reveals that descending geometry is much better for PS identification in the area of abandon Asbestos mine.

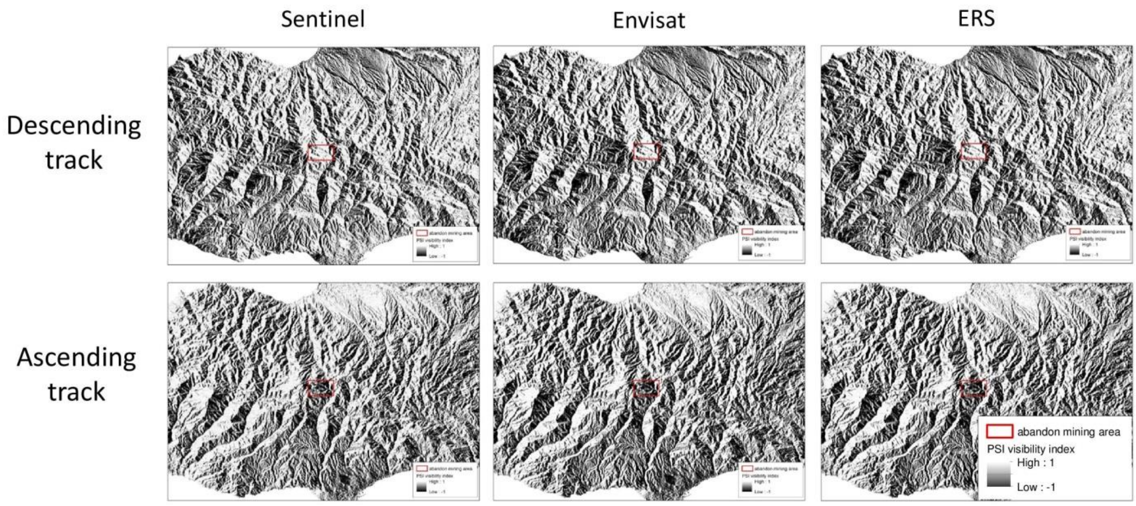


Fig. 2-18 PS visibility index calculated for Sentinel-1, Envisat and ERS satellites for both geometries: descending and ascending.

The PSInSAR processing was done based on 30 Seninel-1A Single Look Complex scenes (orbit number 17739), which cover period 26 July 2016 to 9 July 2017. Time interval between scenes is 12 days. The processing was limited to the area of the central part of Cyprus (Fig. 2-19 red square). It was performed in ENVI SARScape software using SBAS algorithm.

For the final results PS with coherence greater than 0.5 were chosen. Finally 75 691 points were identified, shown in Fig. 2-19.

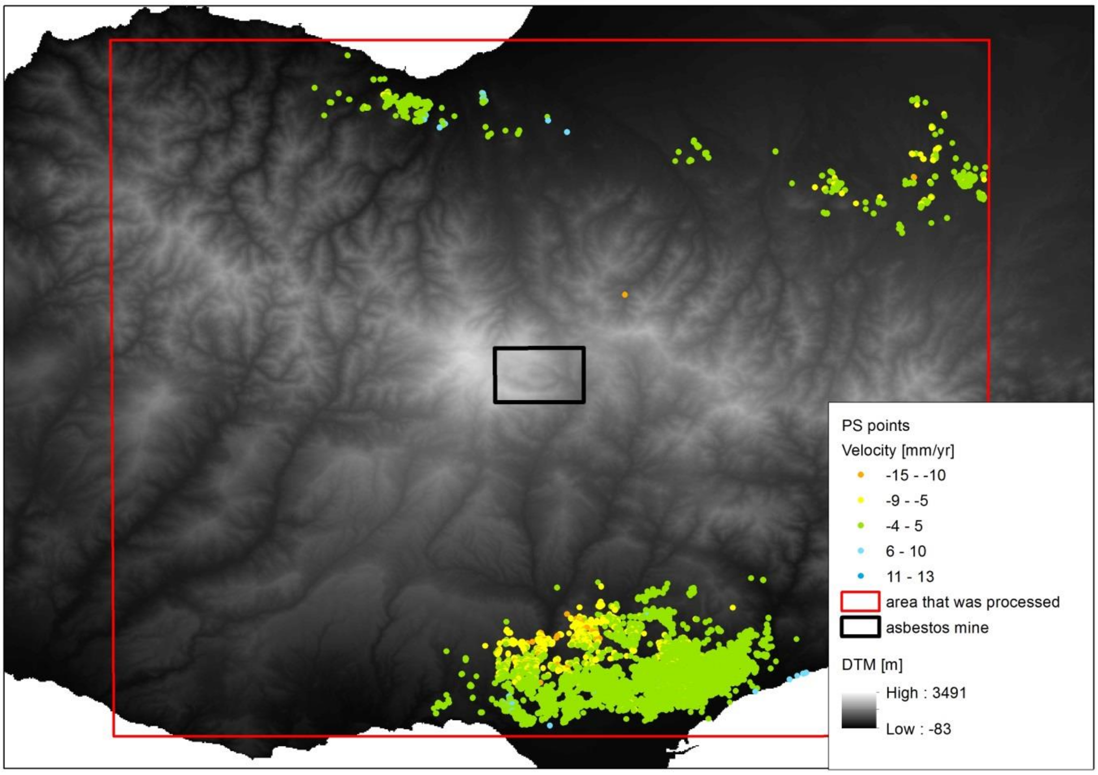


Fig. 2-19 PS points from Seninel-1 shown with the color scale of the average rate of movement in mm per year.

Unfortunately the resulting set of data give no information in the study area of abandon asbestos mine. The points with high coherence values, i.e. the ones that are reliable, are identified only in the more urbanized areas with less vegetation located at the foot of the mountains. These points show stability in the processed period, with no significant movements.

Lack of information in the study area results from the earlier discussed reasons. The area is covered by forest, therefore in C-band it is hard to distinguish reliable PS points. However the processing can be improved by larger set of data (e.g. 40-50 scenes) or data from L-band satellite.

2. Determination of the land use changes and monitoring progress of restoration works

The processing has followed specific steps as shown in Fig. 2-15. In summary the following have been identified:

- Changes of surface area of the mine
- Waste material / Deposition areas
- Changes of vegetation cover
- Change analysis has been very sensitive to acquisition date of the satellite data and to shadows due to intense relief of mining area.

Examples of the Seninel-2 potential for the area is shown on the Fig. 2-20 – 2-22.

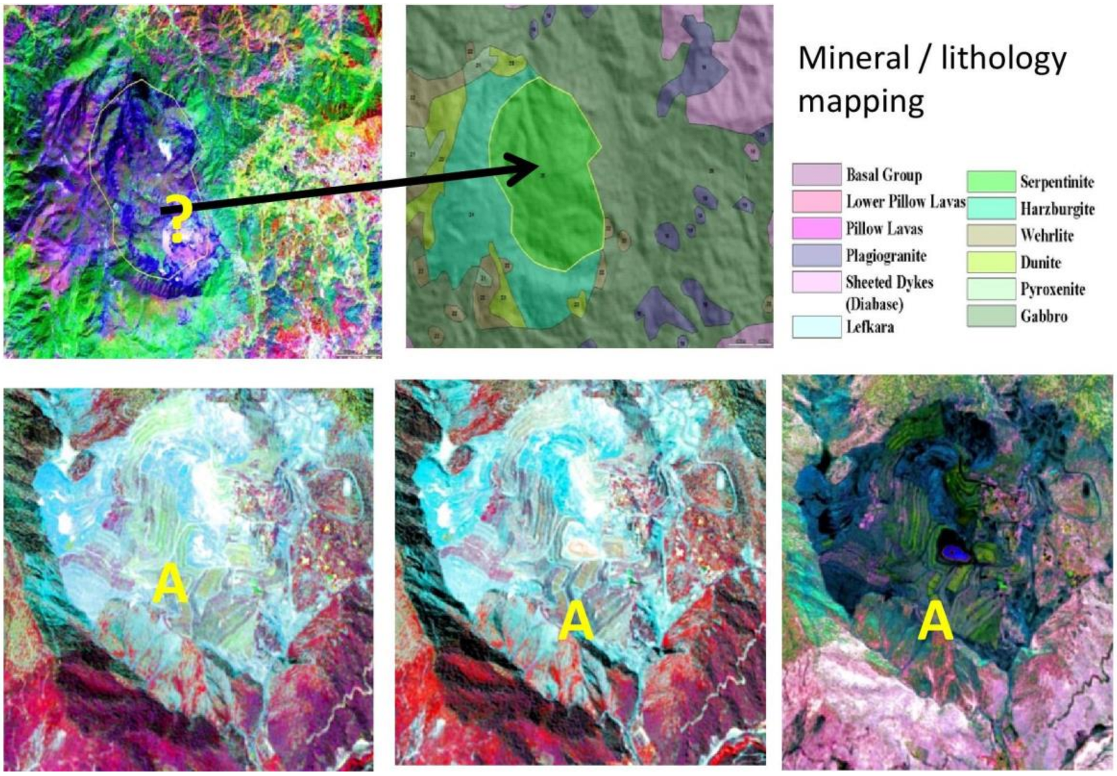


Fig. 2-20 Sentinel-2 multitemporal analysis can support determination of the land use changes and monitoring progress of restoration works.

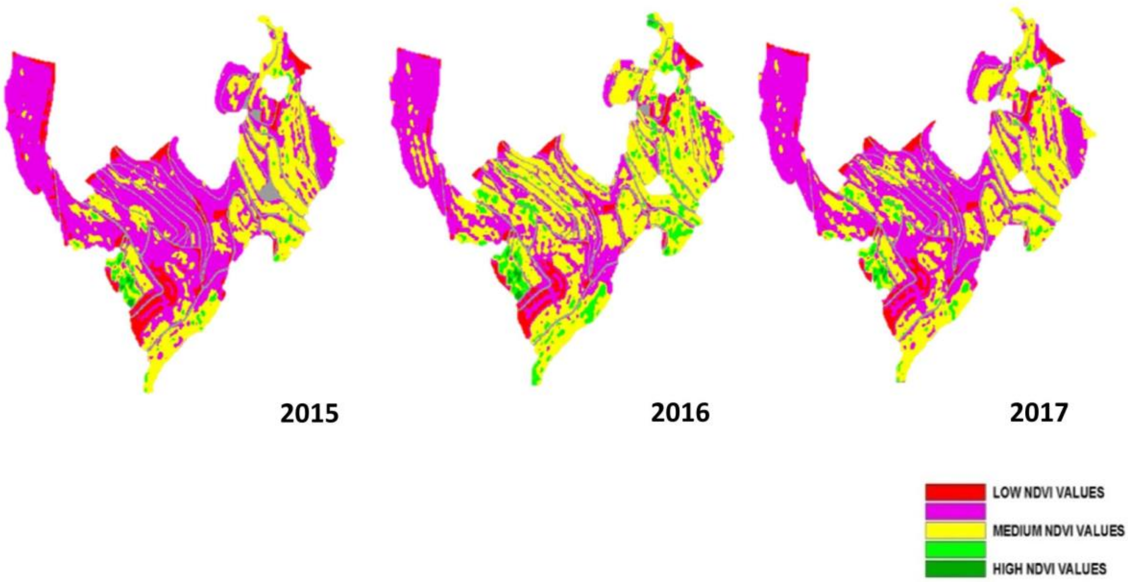


Fig. 2-21 Analysis of the NDVI index for different periods as a support for monitoring of landscape changes and reforestation progress.

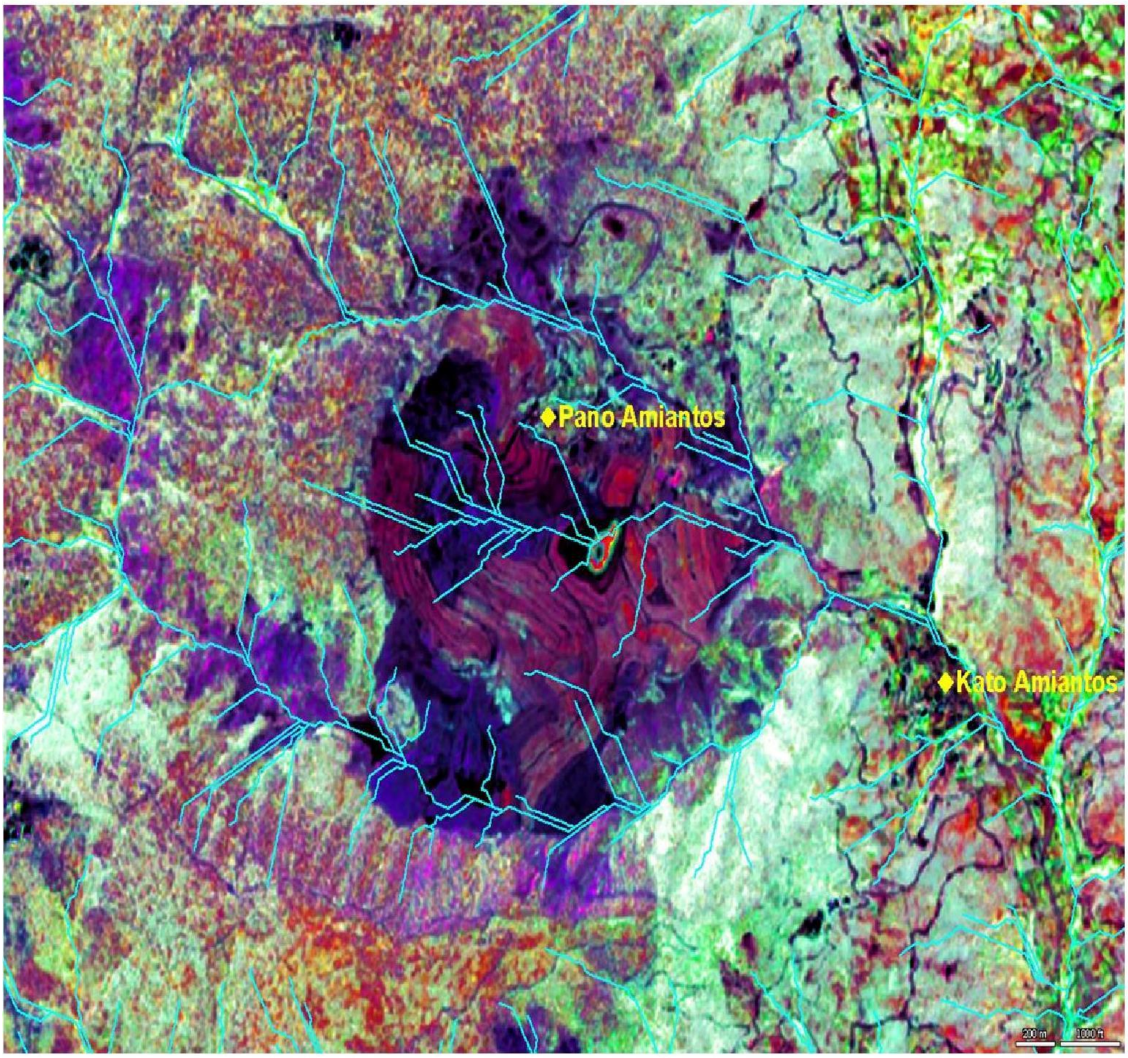


Fig. 2-22 Sentinel-2 analysis for Asbestos Mine rehabilitation: Selected biophysical parameters can be mapped and monitored at regional scales up to 1:25000.

Preliminary results:

- Monitoring is supported through change analysis / The methodology can support field inspections of the “mine” to ensure national regulations are met.
- Temporal resolution of Sentinel 2 data cover needs of the End User as far as regional mapping / monitoring is concerned. Regular updates of related to different parameters can be obtained (Seasonal / monthly or even more frequently)
- Spatial resolution of Sentinel 2 data covers needs for “regional monitoring” of surface mapping of the mining area and the surrounding lands.
- EO tools assist in mapping & monitoring surface activity –Aspects of the activities have to field verified by the End User.
- Field verifications are needed to support the works of the project in all stages of analysis.

Monitoring rehabilitation NDVI

Rehabilitation through reforestation on part of the quarry area has taken place and this can be mapped and monitored quite accurately. Monitoring of “reforestation” is particularly important to be carried out on Asbestos mine and this of special interest to the Forestry Department.

Classification

During the consultation process it has been identified the need to automatically identify not only the surface extent of the surface area of the quarries but also to identify the different activities like deposition areas, waste disposal, active extraction surfaces, reforestation. Results need to delivered in GIS vector format which can then be viewed with high resolution images. Results obtained from unsupervised classification techniques are quite satisfactory but there is a need for the End User to assign the relevant interpretations to the various classes. Supervised classification can also be carried out but the End User needs to define training sets of the various classes. Application can then be applied to all areas of interest and results are to be compared for the different acquisitions of the Earth Observation data. The following analysis is then the same as with the application of unsupervised classification techniques.

Despite important algorithmic developments in recent years, there is still no universal and optimal recipe for remote identification, classification, and quantification of "quarry activities". In the past, linear spectral un mixing has received a great attention from algorithm developers, but so far, the outcomes have not been utterly convincing. Recently, un mixing has been augmented by incorporating the contextual (spatial) information, or by bringing nonlinear methods into the scene. The nonlinear un mixing methods may give more accurate estimates, whereas the spatial-spectral un mixing is exploited to incorporate the pictorial character of the image. it is anticipated that other types of hybridizations to be even more effective. There are many opportunities and promises in hybridization between spectral and feature domains.

Regarding the application of classification techniques, we have not gone far from traditional “image classification” approach, which is hardly comparable to the outcomes of visual techniques, while a system for automated identification of all the different types of "quarry activities" is still absent. Given the richness of contextual information embedded in quarry areas, in the form of texture or zoning, it is conceivable to use this valuable information using spatial-spectral hybrid techniques. Such a system should specifically adopted to analyze the spatial–spatial pattern, as well as the multiple wavelength spectral ranges. The use of ancillary data, which are essential for accurate spectral quantification, makes the processing techniques case specific and non-transferable. This limits the use of automating processing chains and the standardized (qualitative or quantitative) production of 'geo science products’.

Watershed Analysis

Another issue that occurred during consultation process refers to the application of view shed analysis with the purpose to identify surface flows and therefore distribution of pollution.

Identification of Pollution

It is indicated that the developed methodology cannot only support the monitoring activities of the mining area but it can support the: "Poly parametric analysis of different data layers for the identification of problem Areas – i.e. the designation of specific areas where there might be pollution problems and so identify which activities may have to be undertaken.

Remote sensing provides valuable information concerning different environmental parameters. Monitoring is supported due to the multi-temporal character of the data. Generally sufficient data required for environmental mapping are not available and therefore, satellite data can be analyzed to generate GIS database information required for environmental studies. Generated database can be used to assess changes that are taking place in the environment. The added advantage of the proposed approach is that it makes available to end-users a variety of the data and that it helps in efficient analysis and the support of the activities of the End User.

"Activity on the mining area" can be monitored while a general evaluation and quantitative aspects of certain parameters can be accomplished. However, it is also shown that there are restrictions in using Sentinel 2 data due to its medium resolution and key features related to inspections cannot be recognized easily while misinterpretations can also occur. Acquisition of 3D data may also be required to be obtained using satellite or UAV airborne photogrammetric methods in order to get the third dimension of the depth of excavations and / or restoration.

EO tools assist in mapping & monitoring surface mining activity have to be assessed by the “End User".

New environmental policies require many agencies to provide public access to information gathered with public funds. By virtue of its geographically structured approach, an Atlas of Earth Observation processed data offers an intuitive, self-paced, and self-contained way to provide secure public viewing of data such as multi-temporal information land cover / use, and available environmental information. In general the immediate benefits to the End User are as following:

- Mining Site mapping - Mapping Disturbed / undisturbed land - Land use / cover changes - Delineation of areas where potential restoration activities are taking place.
- Track changes of the activities which are implemented through the comparison of multi-temporal images.

- Identification and characterization (by the competent Greek authority) of the nature (authorized or unauthorized) of the changes observed - Compliance with permitting regulations.
- Documentation of the conditions of lands related to quarries.
- Reclamation monitoring.
- Discrimination of geologic setting - Geologic feature extraction to optimize field reconnaissance.
- This is of particular interest to the End User as geologic features need to be mapped in detail.
- Planning exploration activities in other areas in Cyprus - Managing mining activities.
- GIS database creation - Visualization by the Staff and the Public.

It has to be noted that the pilot project work has been accomplished in very strict time limits (involvement for the last three months of 2017) and budget (no additional Earth Observation data could be acquired / no field visits or meetings / no expenses / etc). The action had to be based on freely available data. The support of the End user -Geological Survey of Cyprus is kindly acknowledged.

3. TURKEY - I

3.1. Identification of possible study

3.1.1. Name of the pilot site

Central Anatolian Lignite Basin

3.1.2. Summary

Central Anatolia Region, which covers the Ankara, Sivas, Konya, Çankırı, Yozgat, Karaman and Eskişehir cities (approx. 163.057 km²), has the second biggest lignite reserves (2.692.594.000 tons) in Turkey. Within this province, there exist many active private and governmental exploration and production concessions, most of the production comes from open pit operations. The main extracted raw material from this province is lignite. General characteristics of this lignite ranges from 1.900 to 3.900 Kcal/Kg. The outcropping units in the study area are generally lacustrine sedimentary rocks deposited during the Miocene - Oligocene period and andesitic tuffs and basalts which are intercalated between them. The geology of the region was also synchronized with the tectonic activity along with the sedimentary sequence described above. In particular, these units forming a Tertiary sequence with a thickness of more than 250 m were broken up in parallel with normal faults in many parts of the region and thus a mini graben system was formed. Coal formations were deposited in this volcanosedimentary sequence.

The Association of Geological Researches in Turkey (JADE) has proposed a feasibility study which aim to elaborate accurate quantification and valorization of the coal resource potential in Central Anatolian district in Turkey. The study area originally includes a few number of small coal mines, but it is believed that there is a big potential in this area, comparing the surrounding coal provinces and similar geological signatures. Central Anatolian lignite were formed in a Tertiary lacustrine environment, which was controlled by volcano sedimentary deposition regime and related younger tectonic activities. Therefore all such deposits have almost similar geological section (coal layers are interbedded with tuffs, basalts and gypsum minerals), although formation names are different in several localities. On the other hand, there are small scale open quarries & underground reserves, which have a future potential to turn into a coal province.

3.1.3. Description of the pilot site

The oldest units in the Ankara Group, covering the study area (Ankara province and south) are ultramafics, diabases, pillow lavas and pelagic sediments consisting of oceanic crust remainings. These are the oldest rocks in the study area, results of the rapidly deepening sea, which triggered block faulting that coincides with the expansion of the Paleotethys ocean. These units are sometimes exposed in the study area as

PermoTrias aged debris, Jurassic carbonates and ophiolitic melange units of Cretaceous age.

At the end of Triassic, Paleotethys began to close with the effect of compression forces, while oceanicization was not fully realized. As a result, sedimentary rocks, volcanics and blocks forming the Ankara group gained a complex structure and partly floated on the water.

Tertiary aged sedimentary basins, which are large expanses of coalification in Central Anatolia, developed during the closure of the northern limb of the Neo-Tethys Ocean and later on.

In this process, the Hançili formation (Th), which covers the majority of study area, was precipitated in a river and lake in a continental basin developed by the alluvial fans at its edges. By time, the lake environment became more dominant than the river environment, and the basin gradually became a lake. While sedimentation in the lake continued, the tuffites participated in the sedimentation of the volcanic product, which continued its activity in the region, and the andesites entered to the sediments as sills. The coal in the region (lignite and bituminous shales) developed in this formation under this regime.

During the Eocene, terrestrial and marine environments have been formed in the deep and shallow part of the basin. The alluvial fans developed along the basin and coastal rubble and sandy sediments were deposited. The products of the delta and shelf environments were also precipitated in the system. The volcanic equivalents of the granites also fall on those sediments and joined the sedimentation. At the end of Eocene, all basins were terraced and only alluvial fan and braided river sediments were accumulated.

In Oligocene, the alluvial fan, evaporitic lake and meandering river sedimentation occurred in parallel with the transformation of the region into a totally mountainous terrestrial basin and the drought of the climate. As a result, the gypsum minerals precipitated in the evaporitic lakes and formed considerable thicknesses.

After the Oligocene, the compressive forces influenced the region and north-northwest, south-southeastward collapses developed accordingly. This effect continued till Upper Miocene. It became the most severe in Upper Miocene and formed thrusts faultings in the region. In this period, the inner lakes were filled with agglomerates. The last product of volcanism (basalts spread over the Upper Miocene - Pliocene sediments) is seen in this time.

At the end of Pliocene, volcanism stopped but alluvium fan and precipitation of river sediments continued. The present structural form of the region, is the result of Upper Miocene events as mentioned above.

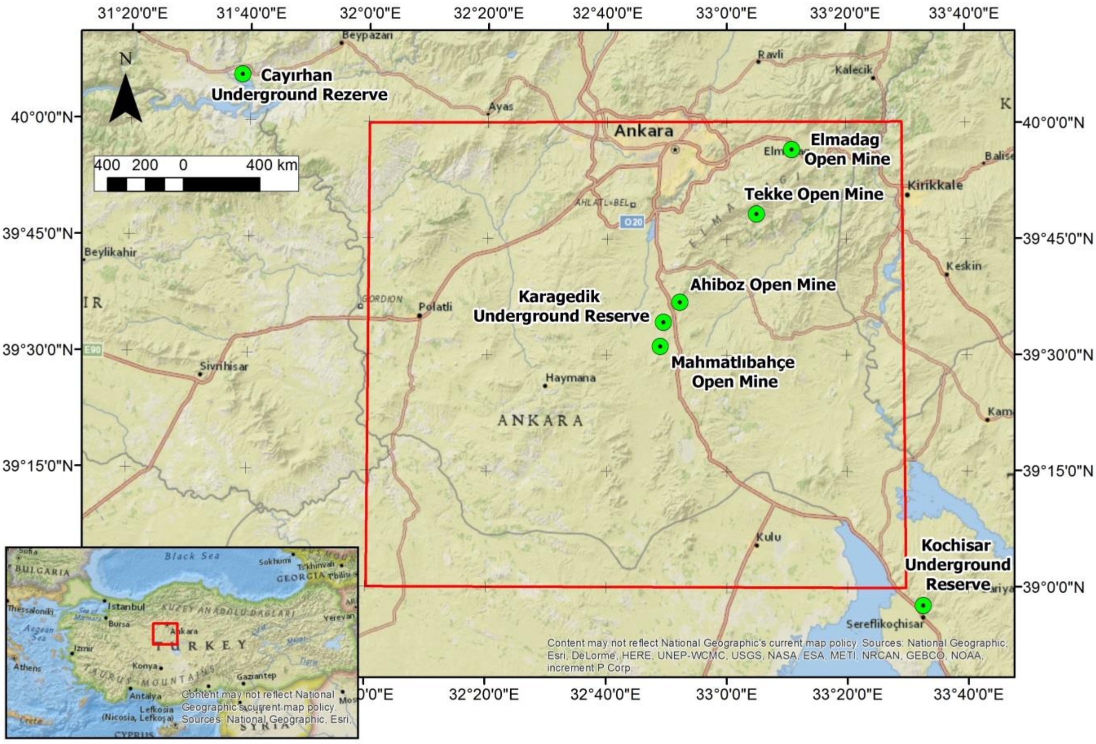


Fig. 3-1 Location of the pilot site area (red square). In green dots lignite mines in Ankara.

Geotectonic location of Turkey

In geostructural terms, the area of Turkey is very complicated. It is part of the Alpide belt stretching from the Atlantic Ocean to the west to the Himalayas in the east. This zone was created in Paleogene Period as a result of the collision of continents of Eurasia in the north and Africa, Arabia and India in the south. As a result of alpine mountain movements, the area of Turkey is divided into three geostructural units (Fig. 3-2):

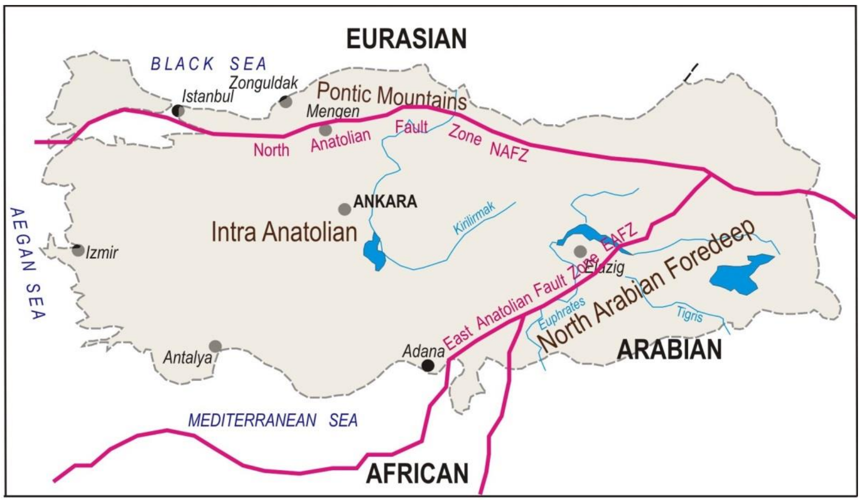


Fig. 3-2 The main geological units of Turkey

- Pontic Mountains,
- Intra Anatolian,
- North Arabian Foredeep,

whose boundaries are set by the North Anatolian Fault Zone and the East Anatolian Fault Zone. Location in such a critical seismic region of Turkey is exposed to the risk of earthquakes of varying strength often exceeding 6 on the Richter scale, resulting in the loss of 100+, or even 1000+ people (17.08.1999 - Izmir - over 17,000 people).

The sediment of the sedimentary rocks representing the Cambrian-Paleogene time interval is lithologically different because it is represented by carbonate sediments and clustered clastic sediments, which, as a result of tectonic movements, have been fractured, cracked, collapsed, and subsequently encapsulated by magmatic intrusion, commonly occurring on the modern morphological surface. Numerous tectonic trenches and morphological depressions have been used as sedimentation tanks for neogene, in which marine and terrestrial sediments were formed, as evidenced by the numerous lignite deposits.

Hard coal deposits

Within the borders of Turkey, there is one occurrence of Carboniferous (middle bashkirian) deposits with coal deposits located in the northern part of the country near Kandil - Zonguldak (Gabzdyl 1994). This is the main Carboniferous coal basin. Clusters, mudstones, sandstones and conglomerates occur in 18 to 24 coal seams with a total thickness of up to 35.0 m. The amount of carbon stocks to a depth of 1000.0 m is estimated at more than 700 million Mg. These are energy and coke coals. The average volatile content of V^{daf} varies between 25 and 45%. The coal mined in some coal mines, amounting to about 5 million Mg, is fully utilized on site for the production of electricity.

In addition, the northern part of Turkey has found carbon black in the Inebol region (the name of the city) and permian age in the southern part of the country. The area of deposits is small (less than 1 km2) and therefore they are not economically significant, although in the past they were exploited (2000 Mg / y) only for local needs.

Lignite deposits

Within the territory of Turkey, several tens of lignite deposits of neogene age (eocene - oligocene - myocene - pliocene) were found, some of which are shown in Fig. 3-3.

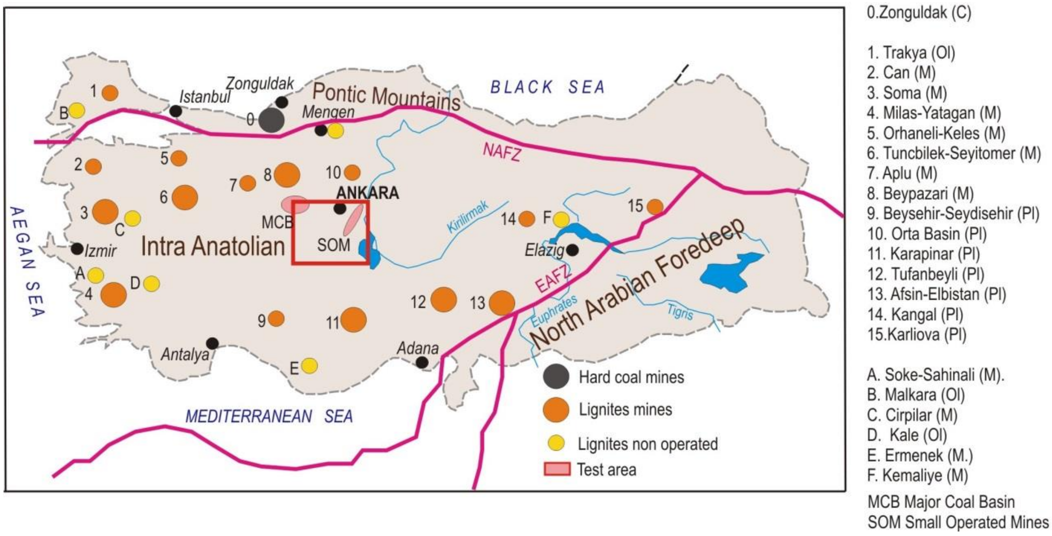


Fig. 3-3 Location of coal and lignite deposits: hard coal Zonguldak (C), lignite developed (1-15), lignite undeveloped (A-F), red square - pilot site area, MCB Major Coal Basin, SOM Small Operated Mines.

These are deposits of various size and shape determined by the location in tectonic trenches and within depressions in the morphological surface of Paleogene volcanic covers. In terms of stratigraphy, the oldest deposits (eocene-oligocene) occur in the northern and western part, Miocene in the area of all Anatolia, and the youngest in its eastern part. These deposits contain lignite with a low degree of metamorphism, characterized by a moisture content (M) above 40%, volatile parts (V) up to 70% and sulfur content (S) up to 8.0%. The thickness of the lignite seams reaches a maximum of 33.0 m and the average value fluctuates between 2.0 and 10 m. The lignite deposits are exploited by open-pit, mixed and underground systems.

Lignite deposits near Ankara

In the vicinity of Ankara, the outcrops of the Miocene sediments with lignite deposits were extracted in several small openings ranging in size from 200 x 200 m to 300 X 3000 m. These areas, as a pilot site area, are arranged along the direction NE - SW between the eastern districts of Ankara and Elmadag in the west and Tekke and Yakupabdal in the south.

On the road E90 (D750) about 3 km south of Ahiboz there is a small excavation of the lignite mine. A similar excavation is located 2.0 km west of Mahmadibahce. Between the last mentioned lignite mines, lignite has been recorded east of Karagedik (Fig. 3-4).

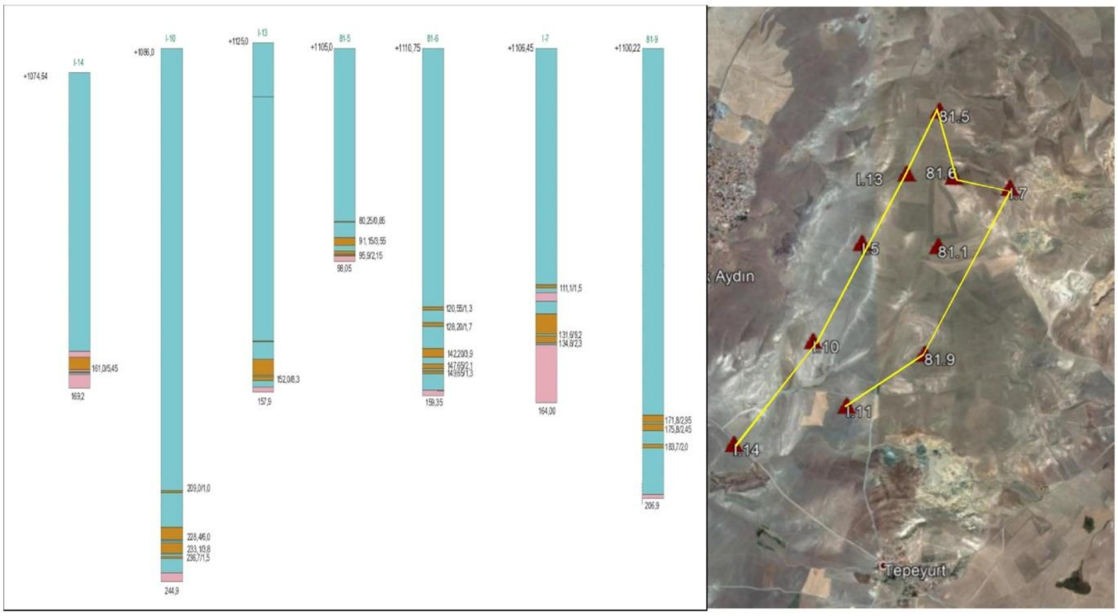


Fig. 3-4 Karagedik underground reservoir (see localization on Fig.3-1). Location of the attached borehole's profiles of lignite series on Karagedik deposit.

It is an undeveloped deposit, occurring under the overburden of Golbasi Fm clastic sediments with a thickness of up to 250.0 m. Pieces with lignite deposits, included in the upper Miocene, occur on volcanic rocks (basalts, andesites, porphyries, tuffs, etc.). This series is made of claystones, siltstones, sandstones locally conglomerates with inserts of limestone and marl, often interlaced with intrusions of volcanic rocks (Fig. 3-4). Direct contact of igneous rocks, according to available chemical analyzes of lignites, does not affect the energy quality of lignites. The thickness of the series with lignite only locally exceeds 40.0m.

The floor of the deposit is located at a depth between 96.0 m in the northern part in the borehole 81-5 to 237.0 m in the I-10 borehole and locally reaches a depth of 262.0 m in the 82-7 borehole in unexplained location. Lignite seams are usually composed of two layers, but there are also cases of six lignite layers divided by plots of thickness from 0.3 to 0.7 m. The total carbon thickness in the exemplary boreholes (Fig. 3-4) varies between 5.0 to 14.0 m. (Tab.1).

Tab. 1 Lignite thickness in the exemplary boreholes.

borehole	altitude	depth	no. of lignites	min	max	sum
81.5	1105,00	98,05	3	0,80	3,60	5,80
81.6	1110,75	159,35	5	1,40	3,90	10,40
81.9	1100,22	206,90	3	2,00	2,95	7,45
81.11	1114,59	237,00	3	0,65	3,70	6,35
82.1	1098,41	174,30	3	1,35	2,85	6,45
82.7	1085,84	322,70	2	1,80	3,20	5,00
I-4	1195,50	136,60	6	0,90	4,35	13,20
I-7	1106,45	164,00	3	1,50	9,20	13,00
I-10	1086,00	244,90	4	1,00	6,00	12,00
I-11	1085,55	283,00	2	5,70	8,30	14,00
I-13	1125,00	157,90	3	0,60	5,30	7,65
I-14	1074,64	169,20	2	0,90	5,45	6,35
I-15	1147,95	238,75	4	0,50	7,55	10,55

It is a deposit with similar geological parameters as neighboring deposits, however, mining parameters are unfavorable in this case and due to them, the possible development of the deposit can only be implemented with an underground system used in several cases in the territory of Turkey. Taking into account the area of the deposit (1x 3 km) and the average thickness of lignite (9.0 m), it is possible to estimate the amount of resources for about 35 - 40 million Mg.

3.1.4. Description of existing data

Association of Geological Researches / Jeolojik Araştırmalar Derneği (JADE) has already developed the Geological GIS database of Turkey, including lignite mines. Several governmental documents and scientific papers are available which describe the properties and statistics of these reserve areas, most of them are open to public access. A vast of scientific papers are available, including remotely sensed data, e.g.: Duzgun et al., 2011, Demirel et al., 2010, Toren and Unal 2001. Several governmental documents and scientific papers are available which describe the properties and statistics of these reserve areas, most of them are open to public access.

For the purposes of the pilot project JADE provided the available geological and mining data in digital form, as pictures, vector kml files, pdf, scanned documentation or text. All the additional data provided by JADE could be classified and described in four main categories:

- Geological maps and information,
- Lignite mines information,
- Documentation of lignite deposit near Karagedik,
- Topographic and land cover data

Description of geological maps and other information on geology in Central Anatolia

The geological information can be viewed in web portal “GeoScience Map Viewer and Drawing Editor”, http://yerbilimleri.mta.gov.tr/anasayfa.aspx/. The portal is provided by General Directorate of Mineral Research & Exploration and the use of it is free of charge. The layers that are provided can be activated by the user by adding them to the current view. These are:
-geological formation
-landslides
-active faults
-faults
-igneous rocks
-earthquakes (last 24 H, last 7 days, last 30 days)
-index of 1/25.000 maps
-index of 1/100.000 maps
-web Mercator grid
-latitude longitude grid

The tool has English version and the formations can be identified in 25K detail with lithology and age, however it's not possible to export/save the screen layers in GIS format (Fig. 3-5 and Fig. 3-6).

Fig. 3-5 GeoScience Map Viewer and Drawing Editor. View of faults, active faults and landslides in the neighborhood of the study area. Study area covers the I28-I29-130 and J28-J29-J30 displayed map sheets in 100K index.

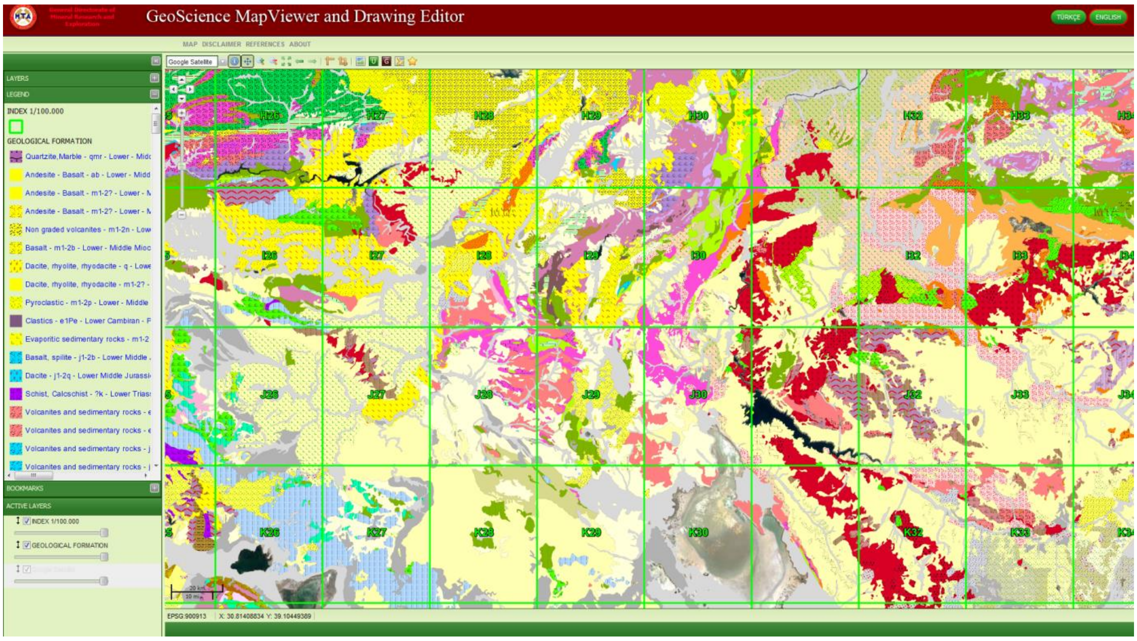


Fig. 3-6 GeoScience Map Viewer and Drawing Editor. View geological formations in the neighborhood of the study area. Study area covers the I28-I29-130 and J28-J29-J30 displayed map sheets in 100K index.

From the information based on the portal, the georeferenced image of geological formation in scale 100k was prepared together with the legend (Fig. 3-7).

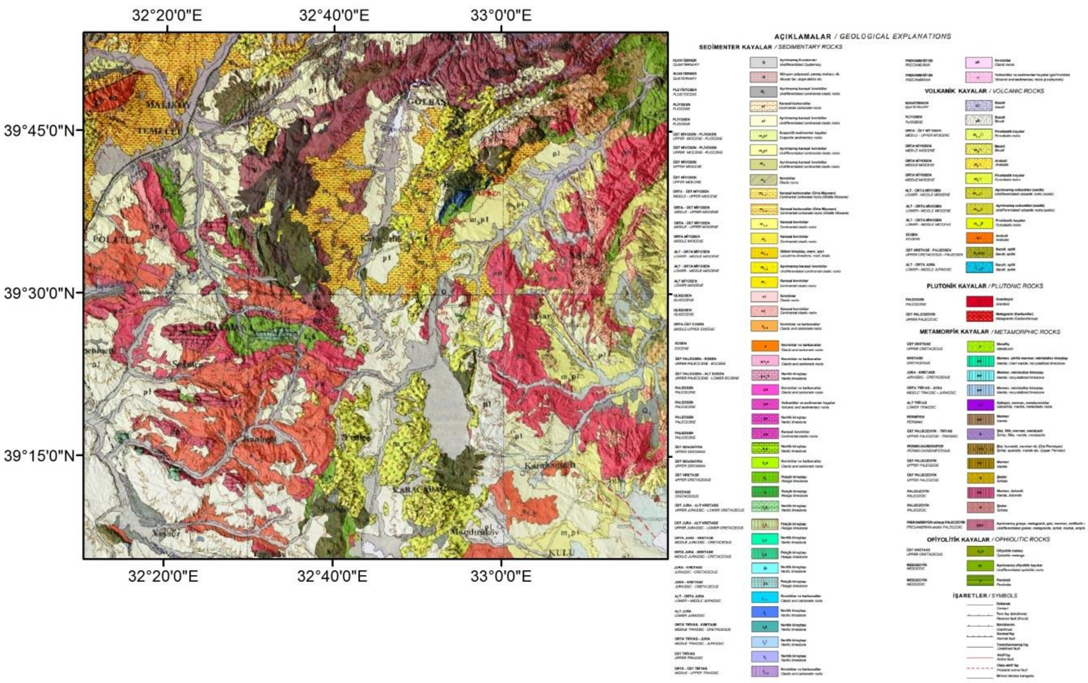


Fig. 3-7 Geological map of the study area in scale 100k based on the GeoScience Map Viewer and Drawing Editor.

Additionally JADE provided also generalized lithology in kml format (Fig. 3-8) and the stratigraphic column (the generalized stratigraphic section of the study area).

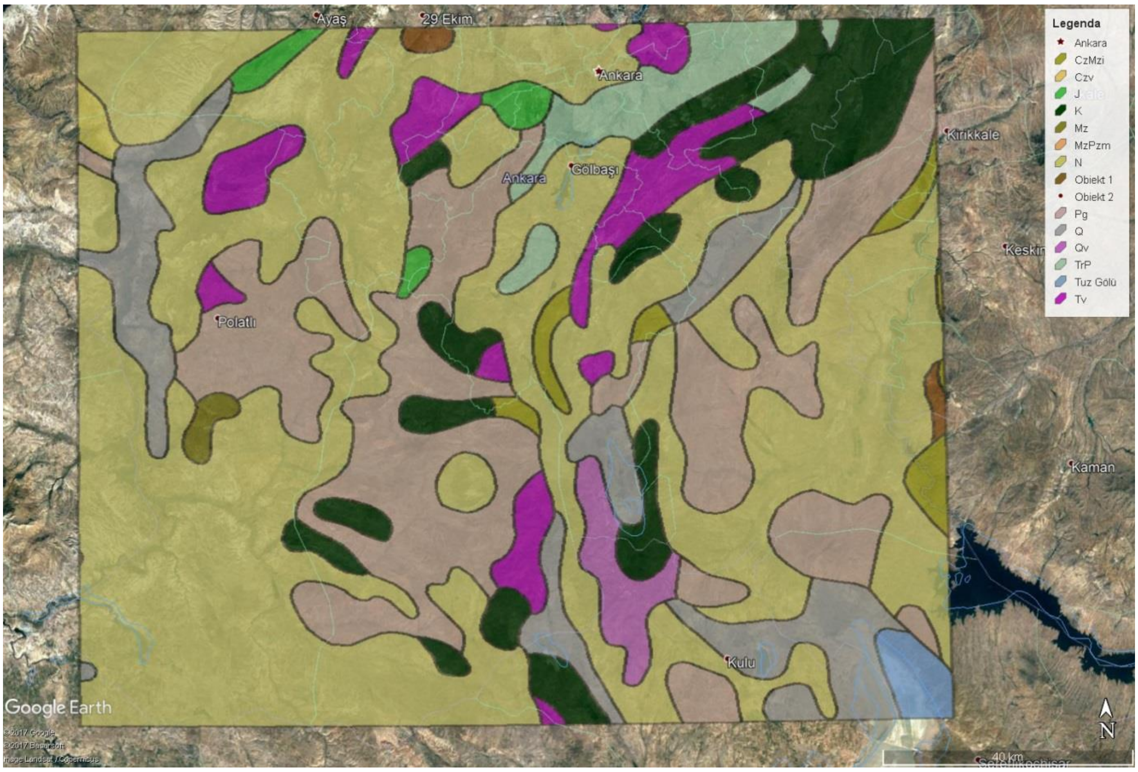


Fig. 3-8 Kml file of generalized lithology of the study area.

Lignite mines information

Developed by JADE location map lignite deposits in the study area was delivered in the form of a KML file. The file contains a point location of open pit mines and undeveloped underground reserves along with mine names (Fig. 3-1).

Documentation of lignite deposit near Karagedik

A description of set of geological boreholes was prepared for one underground reservoir near Karagedik. The list includes 13 borehole profiles in the form of pdf scans (Fig. 3-9). The compiled information on the Karagedik deposit on the basis of the provided profiles is described in the chapter 1.3.

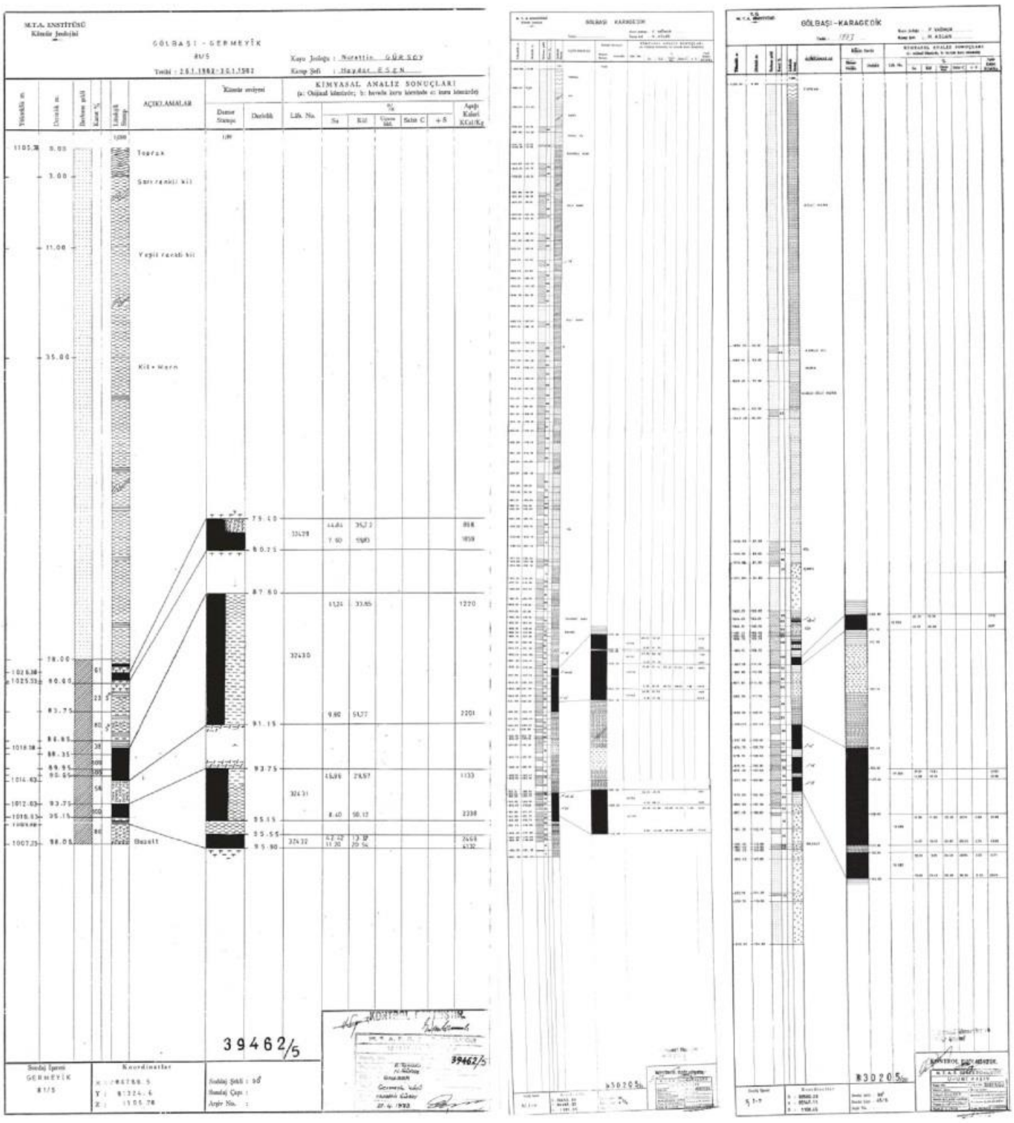


Fig. 3-9 Examples of boreholes profiles in Karakedik underground reservoir.

Topographic and land cover data

Topographic and land cover data are available from various sources and in various formats:
DEM, hydrological & land cover data have been obtained by the EU Copernicus service http://land.copernicus.eu/pan-european/. The pan-European component is coordinated by the European Environment Agency (EEA) and produces satellite image mosaics, land cover / land use (LC/LU) information in the CORINE Land Cover data, and the High Resolution Layers.
The EU DEM http://land.copernicus.eu/pan-european/satellite-derived-products/eu-dem/view/.
The EU-Hydro http://land.copernicus.eu/pan-european/satellite-derived-products/eu-hydro/view/.

The EU-Hydro *public* beta version replaces EU-Hydro beta version (available only internally at EEA) which was created in the frame of GMES RDA Preparatory action 2009-2012 and was based on classification of image 2006, for all EEA39 countries providing 1) a photo-interpreted river network, consisting of surface interpretation of water bodies (lakes and wide rivers) and 2) a modelled drainage network with catchments and drainage lines (derived from EU-DEM v1.0).

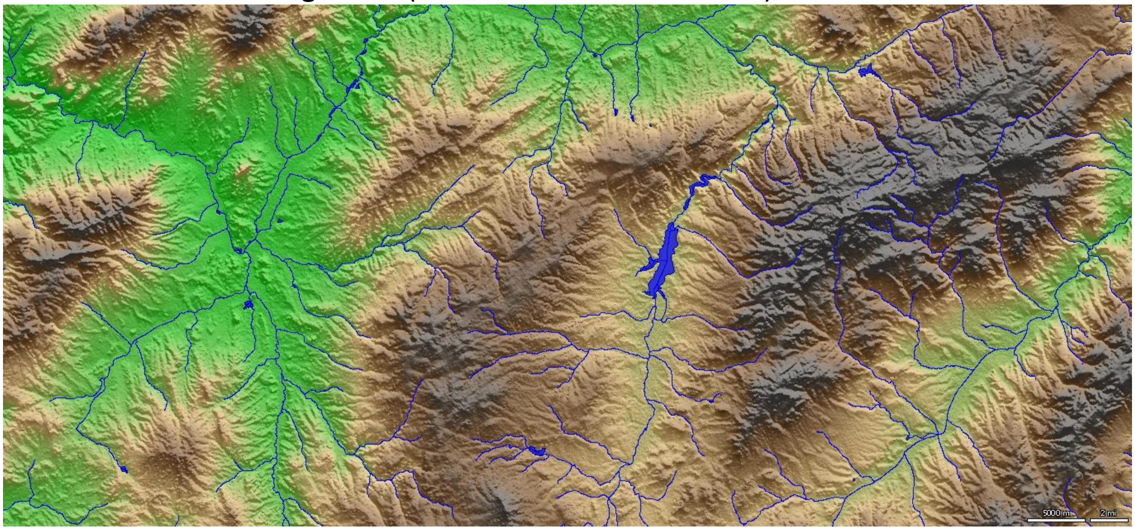


Fig. 3-10 Segment of processed DEM and hydrologic data of the pilot project area

The CORINE Land Cover is provided for 1990, 2000, 2006 and 2012. This vector-based dataset includes 44 land cover and land use classes. The time-series also includes a land-change layer, highlighting changes in land cover and land-use. The high-resolution layers (HRL) are raster-based datasets which provides information about different land cover characteristics and is complementary to land-cover mapping (e.g. CORINE) datasets.

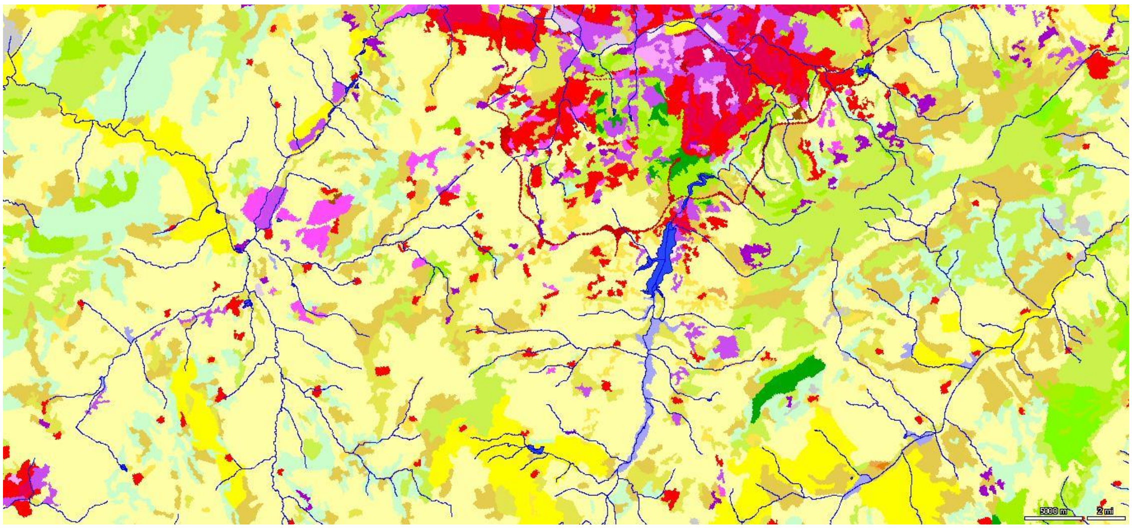


Fig. 3-11 Segment of Corine Land Cover and hydrologic data of the pilot project area

Fig. 3-12 Corine land cover LC/LU of mining areas located in the pilot area study (A & B) on Ortho Photo

It is shown that the mapping scale of LC/LU is coarse for monitoring the mining areas as only the general outline of the mining areas is defined.

It is indicated that satellite data are needed in order to establish an up to date mapping and monitoring system for the mining areas. Sentinel 2 satellite system has been selected to be evaluated for “mapping and monitoring the coal mining areas”.

Sentinel 2 data can be used for monitoring local processes as its specifications are comparable but with enhanced features in relation to other satellite systems like the Landsat series. The data are freely available to the scientific community.

Another type of data is the Ortho-photos provided within TNTgis S/W like Bing maps, Fig. 3-13.

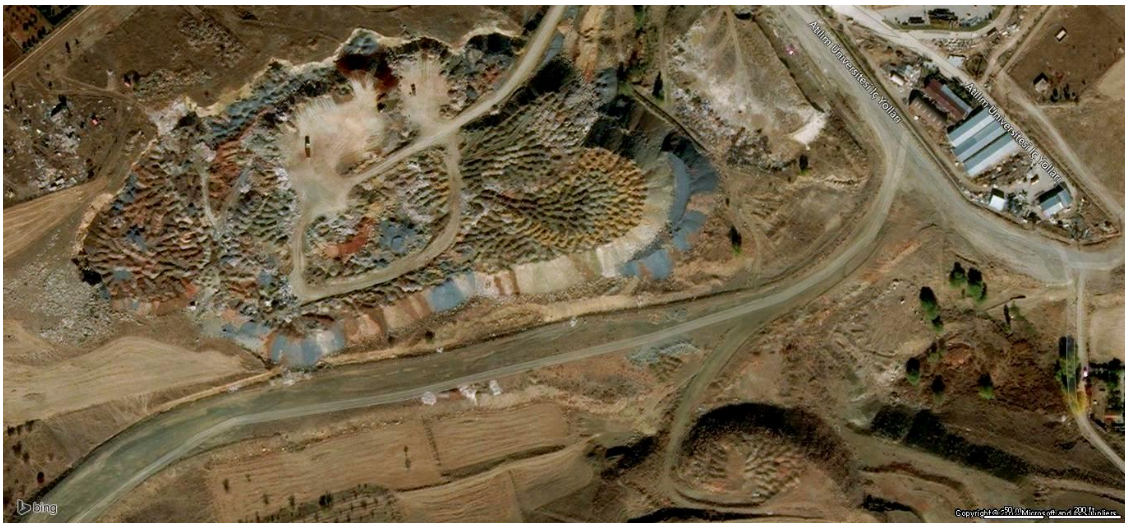


Fig. 3-13 Bing maps ortho-photos integrated within the GIS system - Google Earth can also be synchronized as an external viewer in the GIS system.

3.2. Project description

3.2.1. Objectives and expected results

One of the raised problem in the GEO-CRADLE ROI concerns increasing access to raw materials and the support of mineral exploration management as well as waste materials analysis. This applies to areas that have been operating for a long time, where significant environmental footprint has been left after intensive exploitation, areas that are not well-recognized or are believed to have bigger potential. Well-designed remote sensing methods dedicated to a particular area can significantly assist in analysing the deposit potential as well as identify pollution. For such research areas, methods leading to the GIS database construction should be proposed which helps mining companies to focus on areas for further exploration (prior to expensive conventional methods such as trenching and drilling), thereby reducing fieldwork and minimizing environmental impact.

Most of the raw materials necessary for social development have a geological origin. Through geological knowledge, it can be identified and exploit raw materials resources which play a central role in sustainable development. Geological expertise and competence have the capacity to identify the potential of the open pit and underground resources. On the long term, the availability of geological resources and living space to house our populations are limited. Therefore, building the societies for our future generations challenges us to have a holistic and international perspective of the use of natural resources and the environment. It is then obvious that without proper geological information and intelligence, no society can develop. It is crucial for the sustainable economic and social development of any country in the world and to ensure that the respective governments receive that best advice and background for decisions on geological knowledge and raw materials.

The Earth Observation methods, properly used, can support process of providing security in the field of management of mineral resources, monitors the state of the geological environment, warns of threats and analyze the geological potential. In addition, the use of modern tools and latest technologies can improve relationships between public and private sector.

The use of remote sense data should optimize the resource allocated to the field work priory to detail geological mapping that integrate often a mineral inventory with various levels of details. Satellite and aircraft scenes are used to deliver georeferenced geology and mineral data in digital form which can then be implemented in databases and a geographic information system.

Access to raw materials is a priority for growth. Indeed, mineral resources are critical contributors to the national economies, which grew faster in mining countries than those of non-mineral exporting countries. Their sustainable exploitation can stimulate additional benefits for the local and regional economies and societies by investment in infrastructure, institutional structures and management, encouraging entrepreneurial private activity, private sector participation and encouraging the transitions towards social-market principles and institutions.

In this context JADE has proposed a feasibility study which aim to elaborate accurate quantification and valorization of the coal resource potential in Central Anatolian district in Turkey. The study area originally includes a few number of small coal mines, but it is believed that there is a big potential in this area, comparing the surrounding coal provinces and similar geological signatures. Central Anatolian lignite were formed in a Tertiary lacustrine environment, which was controlled by volcano sedimentary deposition regime and related younger tectonic activities. Therefore all such deposits have almost similar geological section (coal layers are interbedded with tuffs, basalts and gypsum minerals), although formation names are different in several localities. On the other hand, there are small scale open quarries & underground reserves, which have a future potential to turn into a coal province.

The feasibility study should address the important issue of compiling geoscience information that could be further disseminate it to various users including government, business, research and others potential investors to use when making board room decisions on where to invest in minerals exploration.

The project proposal is focused on preparation of GIS databased layers, acquired from remote sensing data:

- Tectonic (lineament) map of the study area
- Geological layers based on satellite classification
- Tuff outcrops only based on satellite classification
- Hydrological (current rivers & water bodies) map of the study area
- Final GIS map of potential coal bearing basin (based on spread of tuff outcrops and possible propagation).

3.2.2. Methodology, methods of implementation

1. Tectonic (lineament) map of the study area

The objective of this study was creation of tectonic (lineaments) map of pilot site using remote sensing data. The term “lineament” was introduced by William H. Hobbs in 1904 (Hobbs, 1904). He defined lineament as “the significant lines of landscape which reveal the hidden architecture of the rock basement”. In other words, we can define lineament as morphologic or tonal feature on the terrain that may represent a zone of structural weakness. It should be noted that the lineaments are not equivalent to faults because these refers to lines indicating the movement of rock formations. The presence of lineaments is a common phenomenon, particularly well visible on satellite images. It seems that they are a reflection of the rejuvenated zones of discontinuities along the weakness zones of the lithosphere. Very extend lineaments, over a few dozen kilometers long are most likely a manifestation of deformations occurring in the deeper layers of the lithosphere. Mapping lineaments or structural features could provide useful information for mineral exploration studies.

The study area is located in Central Anatolia and is 127 km long and 110 km wide (about 14000 sq. km). This region is characterized by quite complex geology. After a preliminary review of the literature, it can be stated that there are limited amount of geologic investigation on the tectonic development and structure of this area. Due to insufficient time to detail analysis of lineaments presented work should be considered only as a preliminary attempt to show the possibilities of remote sensing techniques in tectonic investigations.

2. Environmental monitoring, geological layers, tuff outcrops and hydrological layers designation based on satellite classification

Environmental monitoring is now an integral part of mining operations. Remote sensing enables the identification, delineation, and monitoring of mining areas, including derelict land, and changes in surface land use, (Charou et. al. 2010 / Vasileiou et. al 2012). The aim of this pilot site is to evaluate the use of Earth Observation and in particular of the multi-temporal Sentinel 2 data to map and monitor "lignite mines" on a local scale, and to assess the contribution of Sentinel 2 data on mapping land cover / geologic features of interest to the End User. The general Plan of the methodology applied for this Pilot Site is shown in Fig. 3-14 and it includes:

- Mapping and monitoring (Change analysis / track any detectable potential changes of surface morphology) based on satellite Sentinel-2 data.
- Identification and evaluation of mining activities which are to be archived by developing a Monitoring System (Tool) with the use of EO data.
- Evaluation of the contribution of Earth Observation data on supporting studies of mapping and monitoring of the mines and geological units. Fig. 3-14 shows the overall plan of the Sentinel 2 monitoring system of the pilot project area.

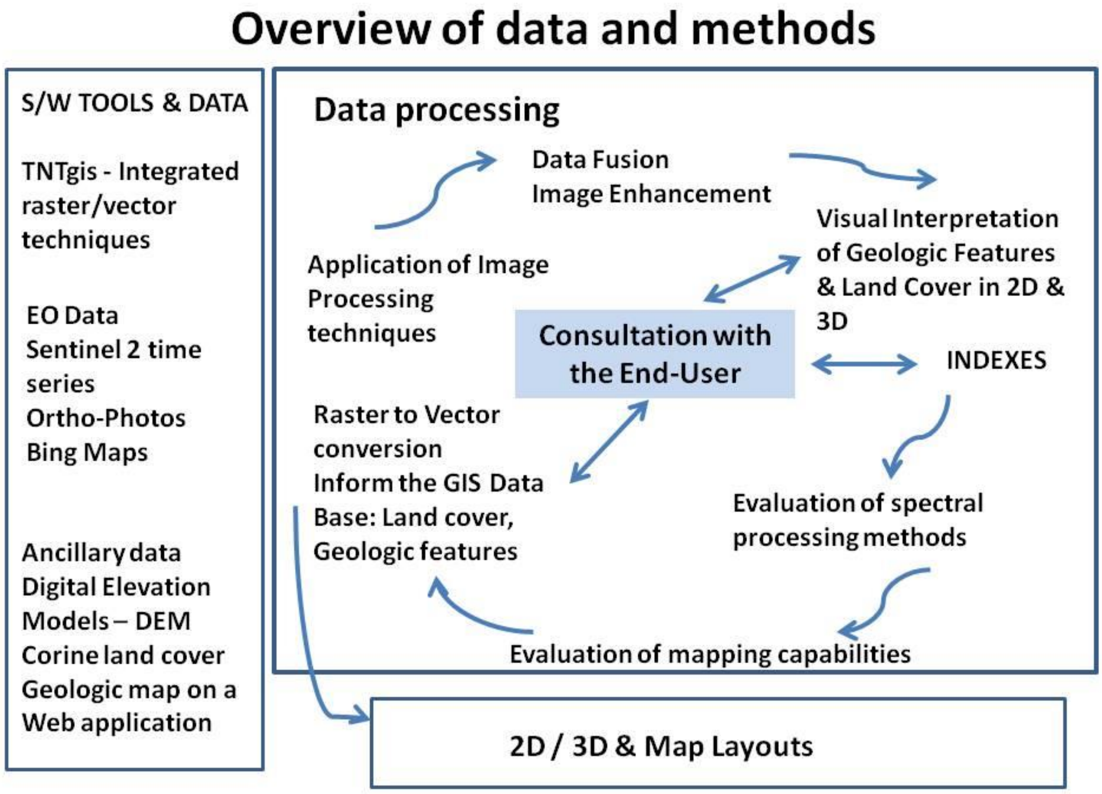


Fig. 3-14 Overview of overall plan of "Data and Processing techniques" applied in the coal mining area of Turkey

3.2.3. Main activities

1. Lineament analysis

The analysis of lineaments can be carried out in two ways:

- Automated lineament extraction
- Manual lineament extraction

Automated method utilized special designed software with algorithms detecting on binary image lines and using different threshold parameters. An example of software for automated lineament extraction is Line module of the PCI Geomatica. However, the automated method has a number of disadvantages because extracted lineaments are very short and often representing artificial linear features like railways and roads. Therefore, a more reliable manual method was chosen for the analysis of lineaments of the pilot site.

In manual extraction method, the lineaments are extracted from satellite images using visual interpretation. The knowledge and experience of expert is the key point in the proper identification of lineaments.

In the manual interpretation of lineaments of pilot site, the following methods have been used:

- Digital Terrain Model (DEM) analysis
- Directional Filters
- Principal Component Analysis (PCA)
- False Color Composite
- Spectral Rationing

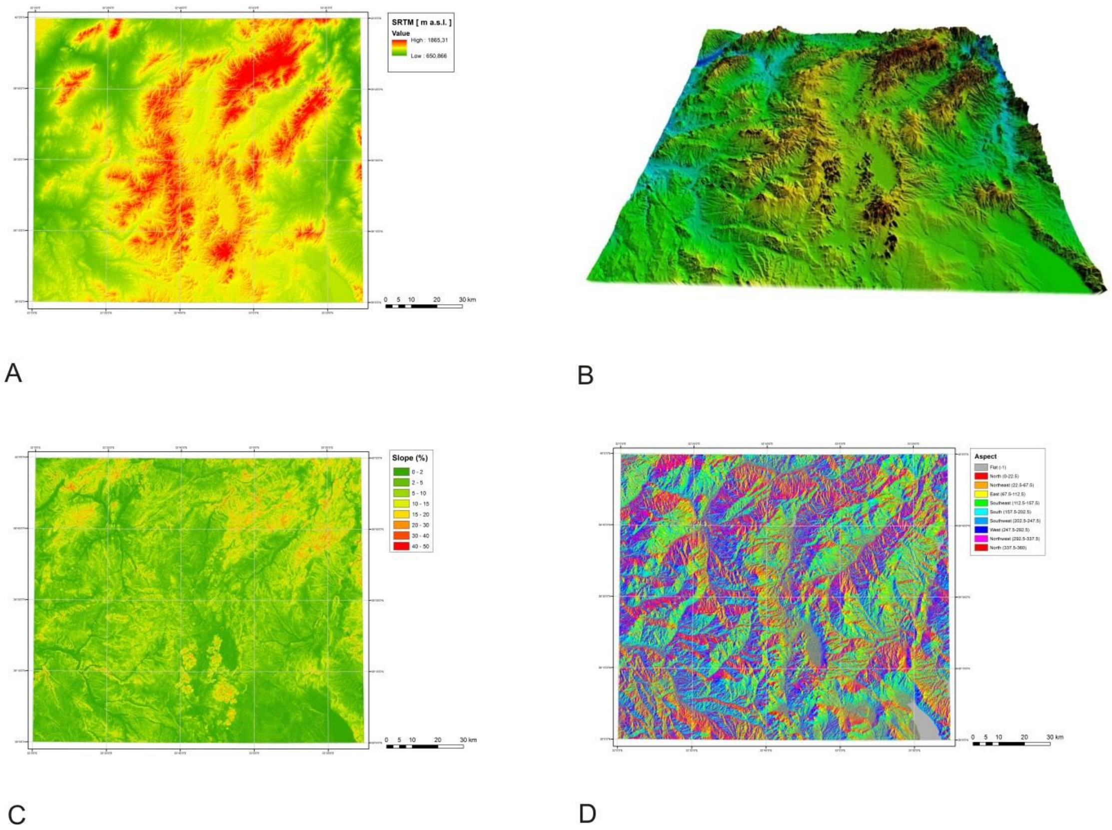


Fig. 3-15 Analysis of Digital Terrain Model of pilot site: A) Relief B) 3D view of SRTM C) Slope D) Aspect.

In this work a DEM from Shuttle Radar Topography Mission **(**SRTM) has been used for the three-dimensional analysis of the terrain. Several DEM product, such as shaded relief (*Fig. 3-15 A*), 3D model (*Fig. 3-15 B*), map of slopes (*Fig. 3-15 C*) and aspect of terrain (*Fig. 3-15 D*) have been calculated for identification of lineaments.

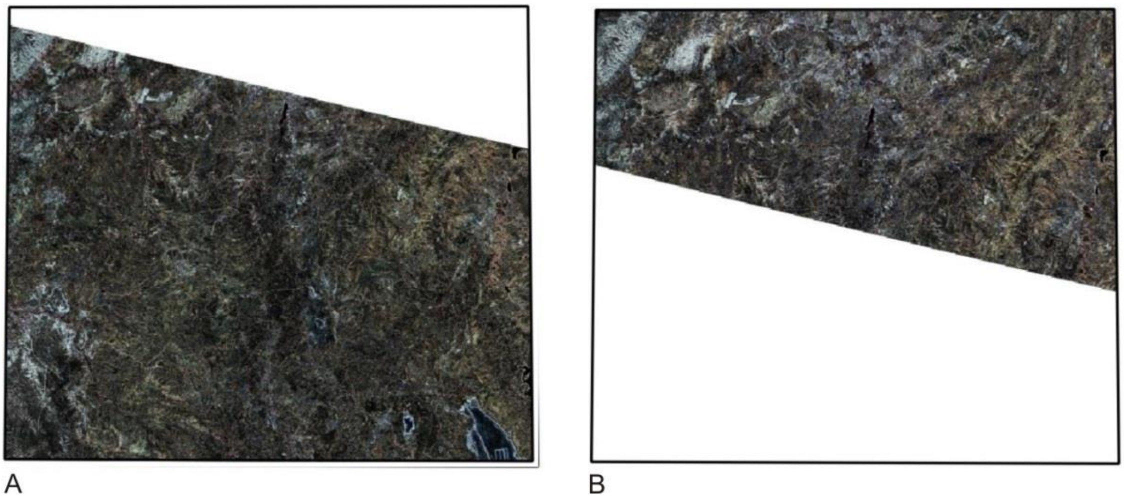


Fig. 3-16 Sobel Directional Filters 1-2 A (Landsat 8, 2016.10.21) and 1-2 B (Landsat 8, 2016.11.22).

Directional filters are used to enhance on the image linear features that trend in a specific direction. In remote sensing the Sobel and Prewitt are the most often used kernels. Examples of Sobel directional filter applied for the NE-SW direction are shown on Fig. 3-16 A (Landsat 8, from 2016.10.21) and Fig. 3-16 B (Landsat 8, from 2016.11.22).

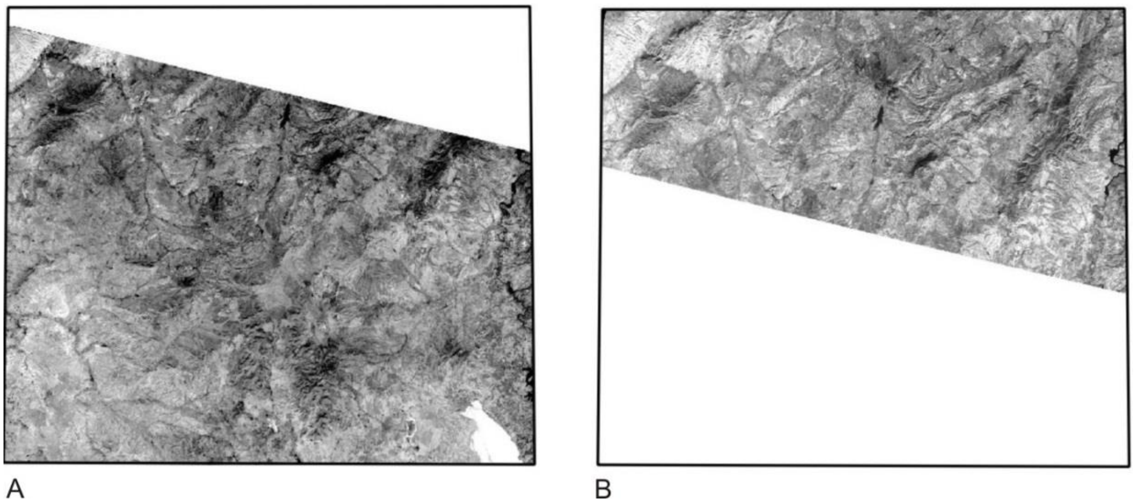
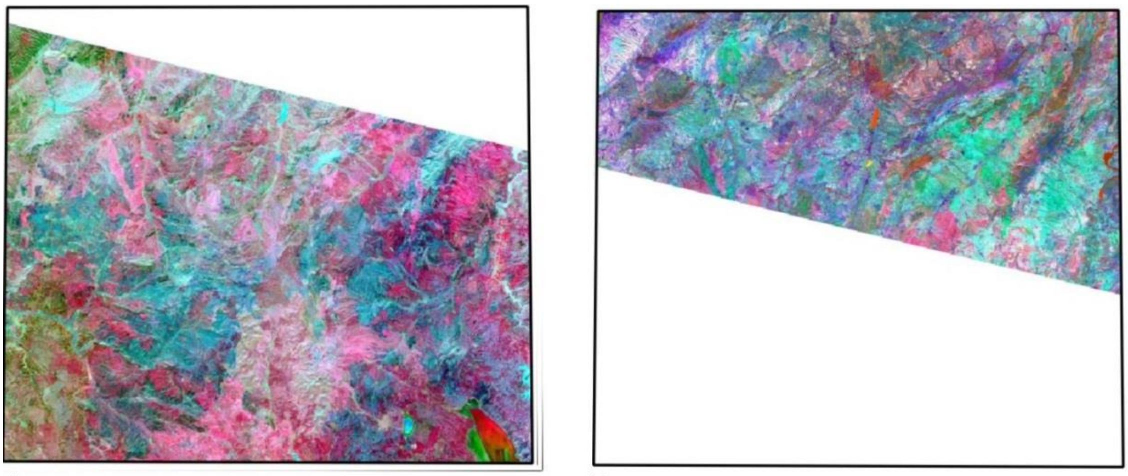


Fig. 3-17 Principal Component Analysis (PCA 1) for Landsat 8 (A - 2016.10.21 and B- 2016.11.22).

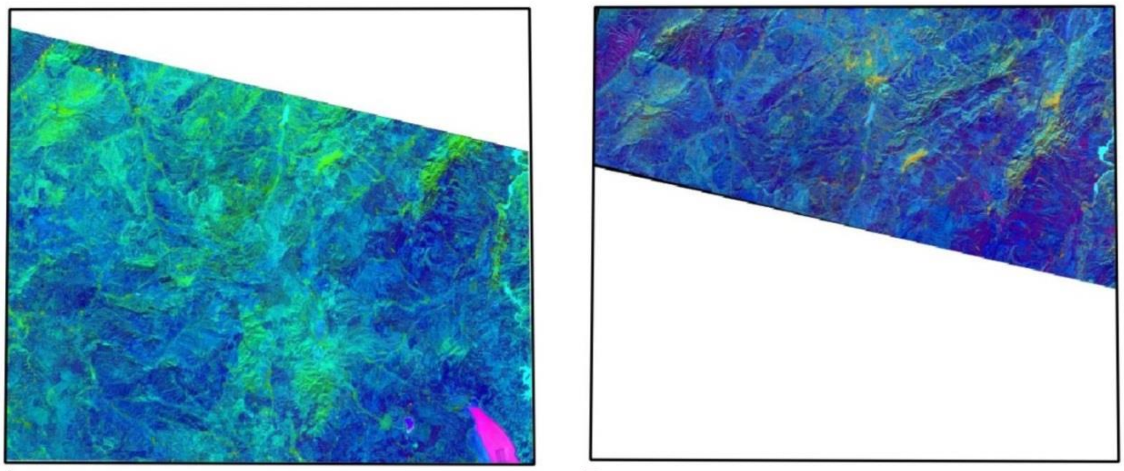
Principal Component Analysis (PCA) is used to compress multispectral data sets into new coordinate system to extract useful information from image. For manual extraction of lineaments, PCA 1 for two Landsat 8 and bands 2,3,4,5 and 7 were created.



A B

Fig. 3-18 False Color Composite of Landsat 8 (1 A – Landsat 8, 2016.10.21 and 1B – Landsat 8, 2016.11.22).

False Color Composite is used for increase interpretability of image through creation different combination of 3 bands. These color combinations helps to identify linear features on the image. For example, for Landsat 8 image the best combination is false color composition utilizing "geological band" (7), near-IR (5) and blue band (2) (Fig. 3-18).



A B

Fig. 3-19 Ratio 7/5, 2/3, 4/5 of Landsat 8. (1 A – Landsat 8, 2016.10.21 and 1B – Landsat 8, 2016.11.22).

Ratio images are created by dividing spectral value of one band with value of another band. Spectral rationing in RGB composite are characterized by better contrast than typical image. For the pilot site ratios of bands 7/5, 2/3 and 4/5 (Landsat 8) is shown on Fig. 3-19.

2. Environmental monitoring, geological layers, tuff outcrops and hydrological layers designation based on satellite classification

Initial processing for mapping and monitoring is based mainly on satellite Sentinel-2 data.

The basic S/W tool used for the integrated analysis of both raster and vector data is the TNTgis software. Research has been accomplished following step by step analysis including (1) Pre-processing of EO data, (2) Image processing, (3) Estimation of Indexes, (4) Application of GIS techniques, (5) Evaluation of techniques.

Various image processing and vector GIS techniques are used for the analysis of the satellite imagery and the collected map data.

Pre-processing

Identification of areas of interest with respect to lignite mining area as this has been identified by the End User. Application of atmospheric correction techniques. Resampling was carried out using the bi-cubic method.

Image Processing

Colour composites: Various pseudo-colour composites like the RGB-843 have been used of the Sentinel 2 data in order to emphasize the quarry areas, which have high spectral reflectance. The composites accentuated the mining areas and discriminated vegetation from barren soil.

Intensity hue saturation (IHS) images: different resolution data were combined using data fusion techniques. This was effective for the land cover and the interpretation of geologic features because complementary information for the same target area was combined. The IHS transform was used to fuse the bands of higher panchromatic spatial resolution with the multispectral bands of the Sentinel 2 so that the inherent land cover classes of "mining areas" could be identified. PCA has been applied of the bands with higher resolution for data noise reduction, while PC1 component has been used as the panchromatic image -PAN in the data fusion process. Final image products derived from this procedure was the 8,4,3-PAN and / or other RGB-PAN composites.

NDVI calculation for vegetation and masking. Calculation of Water Indexes so as to map water surfaces as this has been requested by the End User, Fig. 3-20. It is indicated that surface waters can be mapped / monitored regularly and the GIS can be updated. "Shadows" may impose inaccuracies in high relief areas.

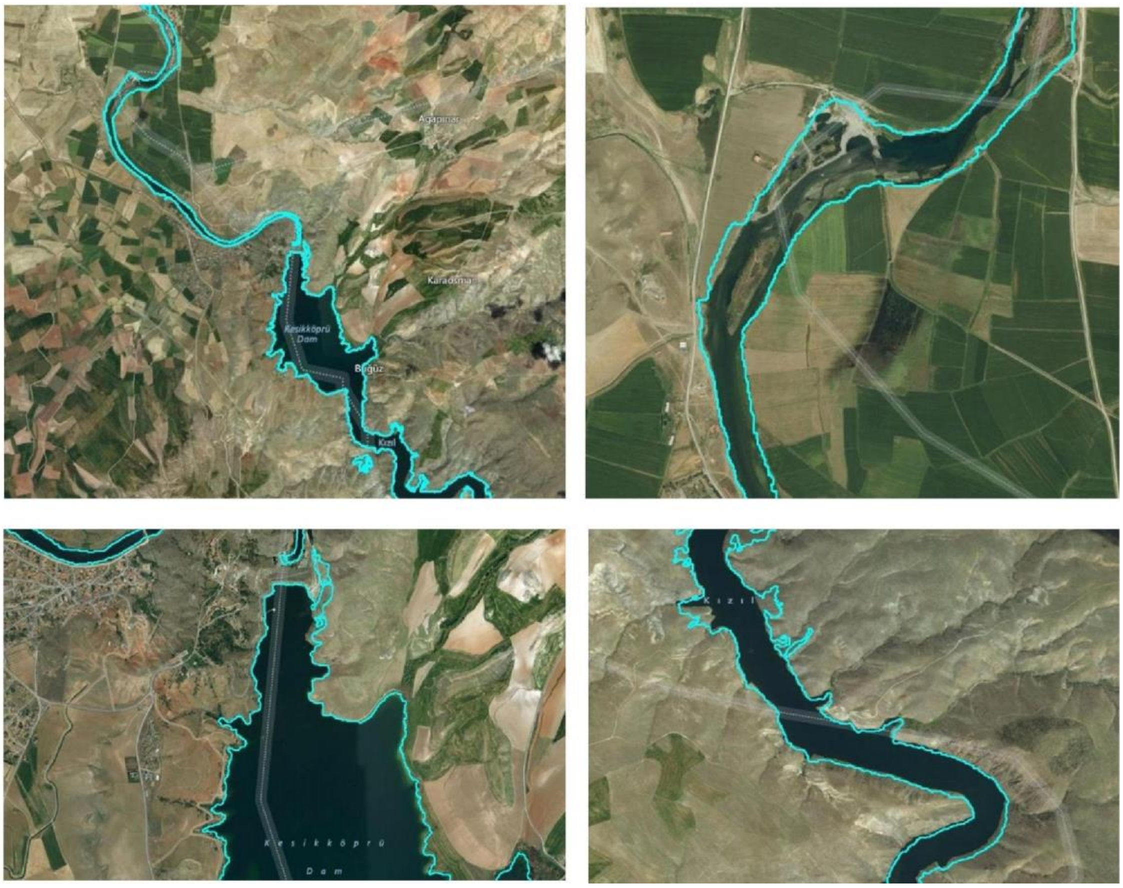


Fig. 3-20 Water surfaces as they have been mapped on the Sentinel 2 image

Map layouts in 2D or 3D formats and as Stereoscopic images using the available Digital elevation Model of Copernicus.

Classification

Image Classification Unsupervised classification techniques using neural networks: Artificial Neural Networks (ANNs) are generally quite effective for the classification of remotely sensed data (Vassilas and Charou 1999) and it includes:

Automated combination of the classification result of multi-temporal imagery: Automated conversion of raster to vector data: Cross interpretation with the corresponding map data and observations acquired on the Ortho-photos. However, this technique has not been applied in this pilot project area as there are no detailed maps available even though there is an interest by the End User for mapping the lithological type of tuffs. There are also restrictions as land cover imposes problems in identifying certain lithologies of geological formations. It is indicated that other techniques referring to identification of specific target minerals related to the geologic formation of tuffs may be more effective. This requires other types of Earth Observation data and processing techniques. A short review is to be given at a later time if this of interest to the End User.

Discrimination of geologic setting

A short visual evaluation of the geologic information provided by the Geoscience Map Viewer has been included. As it is shown on the Fig. 3-21 more "geologic information" is shown on the processed Sentinel 2 image (B) than the geologic map of the Map Viewer (A), Fig. 3-21.

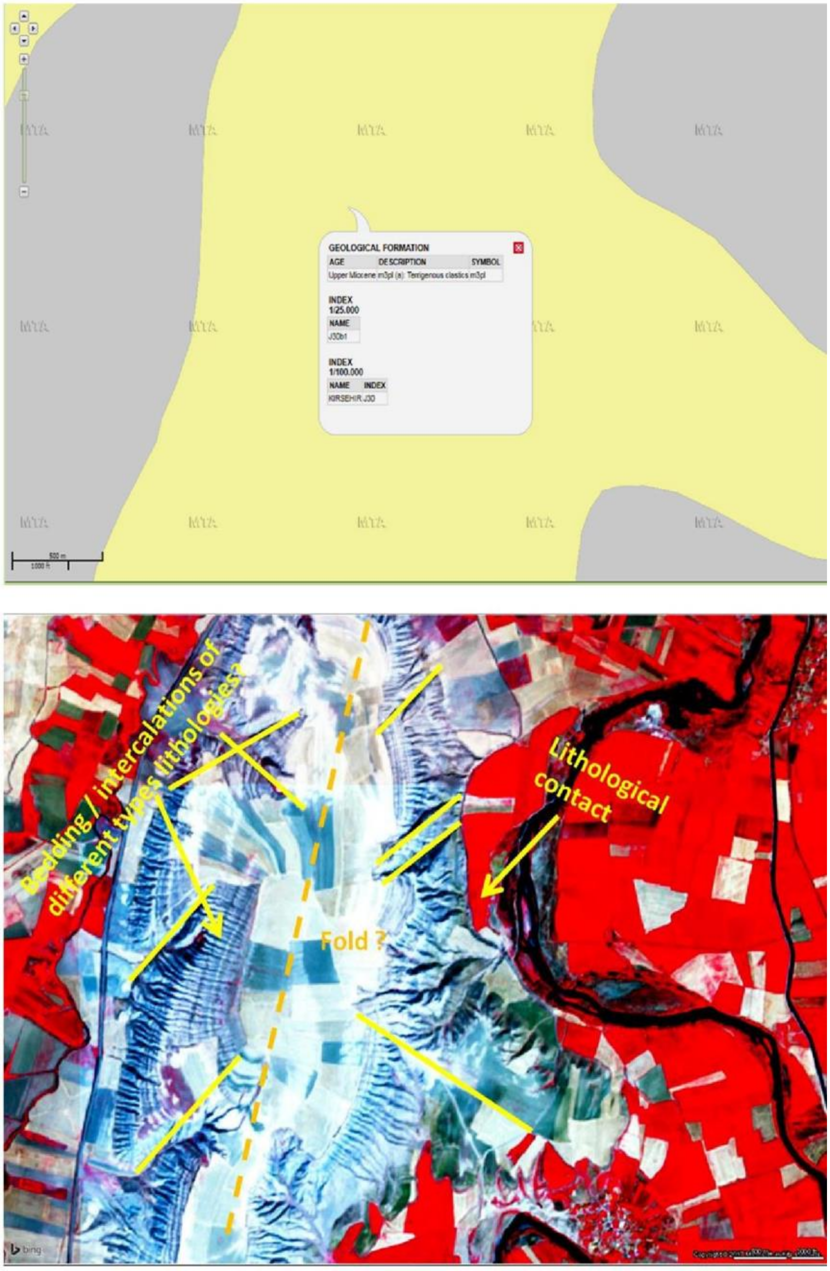


Fig. 3-21 Synchronized views of the same area as shown (top) on the Geoscientific Viewer and the GIS - enhanced and annotated Sentinel 2 image (bottom).

GIS techniques

All ancillary data selected in this study are aggregated in the GIS system. Extraction of the topographic variables (shading relief, slope & aspect) has been implemented. It is anticipated that there is a need to disseminate information of collected and processed Earth Observation and GIS data using electronic means (free software) which are to be dedicated to cover the End User needs. This need is further enhanced as processed data have to be delivered in full spatial / spectral and temporal resolution.

The processing has followed specific steps as shown in Fig. 3-14.

3.2.4. Results of the pilot site analysis

1. Lineament statistics and final map generation

Lineaments extracted from 5 different techniques (DEM, directional filters, PCA, false color composite and rationing) were linked together for preparation the final lineament map (Fig. 3-22). Duplicated lineaments and lines representing roads and railways were delated from the map composition. After compilation of final map basic statistics were calculated (Tab. 2). The total number of lineaments generated from mentioned above methods are 2109 and total length is 3694 km. Additionally rose diagram of lineaments (Fig. 3-23 A) and density map (Fig. 3-23 B) were prepared. According to diagram the main directions of lineaments are NE-SW and SE-NW. For complete view of lineament map of pilot site faults from geologic map at the scale 1: 100000 were added. As a source information about faults and active we used data from web portal “GeoScience Map Viewer and Drawing Editor” (http://yerbilimleri.mta.gov.tr/anasayfa.aspx). The main trend of faults in the pilot site is SE-NW, the same like primary direction of extracted lineaments. Probably this direction of faults is related with continuation of the Tuz Gölü fault zone. Second main direction of faults in analyzed region is NE-SW. It seems that this trend is continuation of Kirikkale-Erbaa fault zone.

Tab. 2 Basic statistics of lineaments over study area.

Start Angle	End Angle	Length[m]	Number
0	15	262141	175
15	30	342242	149
30	45	346356	182
45	60	287087	171
60	75	304765	165
75	90	362347	213
90	105	272817	243
105	120	353606	179
120	135	361067	207
135	150	292348	166
150	165	263036	135
165	180	246374	124

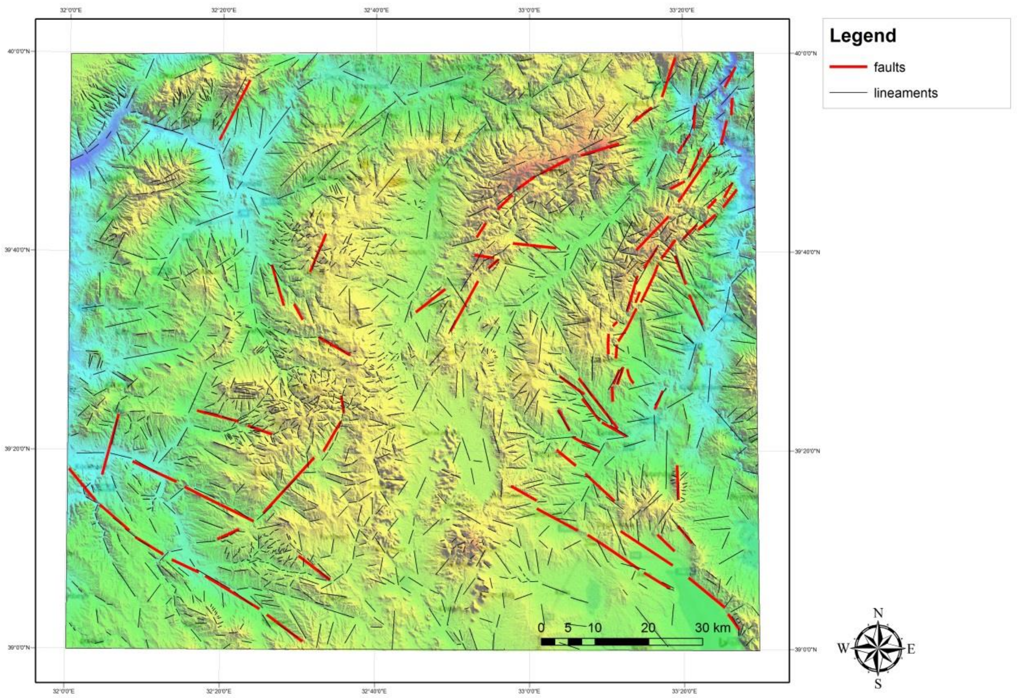
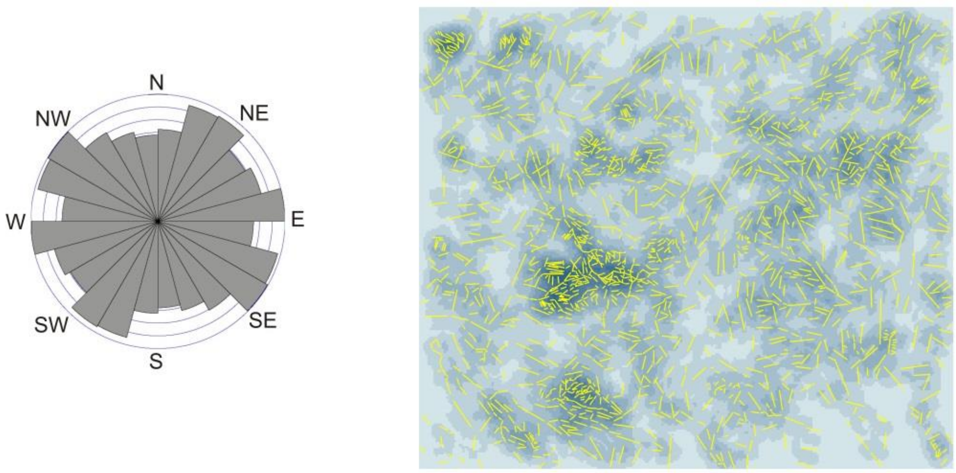


Fig. 3-22 Final lineament map composition.



A B

Fig. 3-23 Rose diagrams from extracted lineaments (A) and lineament density map (B).

2. Environmental monitoring, geological layers, tuff outcrops and hydrological layers designation based on satellite classification

Preliminary results:

- Monitoring is supported as Sentinel 2 data provide up to date information while Corine Land Cover is updated ~every six years.
- Temporal resolution of Sentinel 2 data cover needs as far as regional mapping / monitoring of land cover and geological mapping is concerned. Regular updates related to different parameters can be obtained (Seasonal / monthly or even more frequently).
- Spatial resolution of Sentinel 2 data covers needs for "regional mapping and monitoring" of surface of the mining areas and the surrounding lands.
- EO tools assist in mapping & monitoring surface activity –Aspects of the activities have to be field verified in order to reach concrete interpretation results.

The example of the Seninel-2 potential for the area is shown on Fig. 3-24 and 3-25.

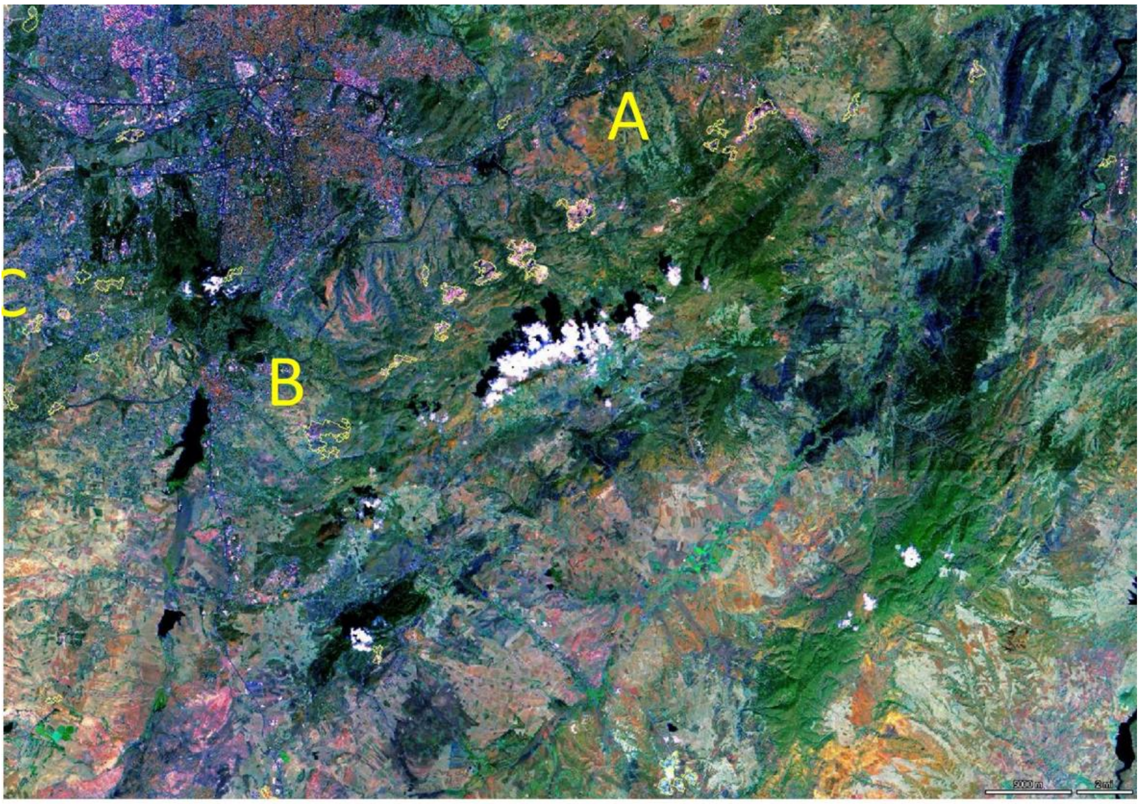


Fig. 3-24 All mining areas of the area can be mapped and monitored (location of the mines indicated by A, B and C).

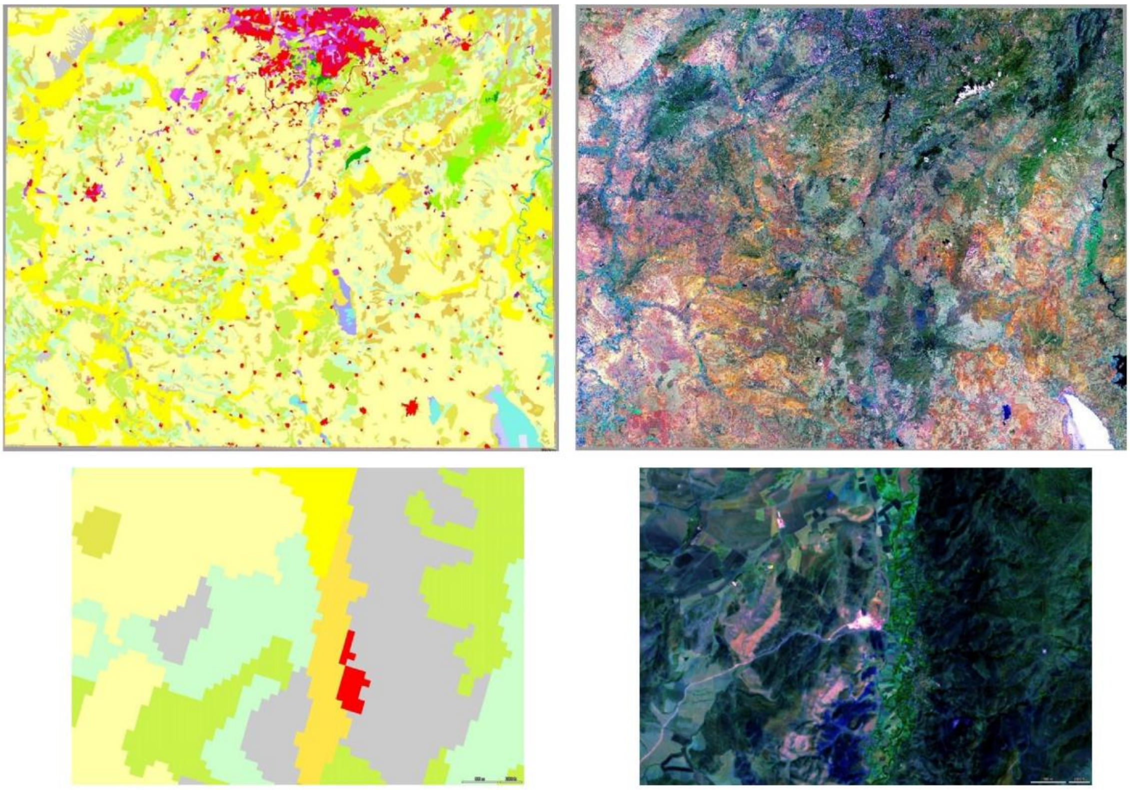


Fig. 3-25 Sentinel-2 RGB composition (right) can be used for updating land cover data from Corine Land Cover (left).

Monitoring the lignite mines

It is indicated that the developed methodology cannot only support the monitoring activities of the mining areas but it can support the: "Poly parametric analysis of different data layers for the identification of problem Areas – i.e. the designation of specific areas where there might be pollution problems". Rehabilitation activities can also monitored quite effectively.

Summary of results

In general the immediate benefits to the End User are as following:

- Mining Site mapping - Mapping Disturbed / undisturbed land - Land use / cover changes - Delineation of areas where potential restoration activities are taking place.
- Track changes of the activities which are implemented through the comparison of multi-temporal images.
- Identification and characterization (by the competent Turkish authority) of the nature (authorized or unauthorized) of the changes observed - Compliance with permitting regulations.
- Documentation of the conditions of lands related to mining areas.
- Reclamation monitoring.

- Discrimination of geologic setting - Geologic feature extraction to optimize field reconnaissance.
- This is of particular interest to the End User as tectonic features need to be mapped in detail.
- Planning exploration activities - Managing mining activities.
- GIS database creation.

4. TURKEY – II

4.1. Identification of possible study

4.1.1. Name of the pilot site

Çelebi-Kesiköprü Iron-oxide mineralization district, Kırıkkale, Turkey.

4.1.2. Summary

The Çelebi-Kesikköprü district is a main Fe-producing district in Central Turkey. The district is also regarded to have high potential for polymetallic Fe-W and Cu vein ores. Intrusion of magmas with cak-alkaline and alkaline characteristics resulted in the formation of skarn deposits enriched in Fe-oxide minerals, and Fe-oxide-Cu-Au (IOCG) deposits (Kuşçu, 2001). The ore occurrences are observed to be hosted by calcic skarn zones. Whole-rock geochemical compositions of plutonic rocks associated with Fe-skarn deposits suggest, a possible potential both for Cu and Au (Kuşçu, 2001).

Based on our preliminary field-observations, some active operating pits along with abandoned pits scattered around in the district may pose adverse effects on the environment. Mitigation measures including environmental restoration may be required for environmental-friendly mining in the district.

4.1.3. Description of the pilot site

The Çelebi-Kesikköprü district is located between Çelebi and Kesikköprü townships, Kırıkkale, Turkey. The district is accessible from the Bala-Kaman highway, about 100 kilometers from Ankara. A series of skarns has produced ore with grades of 50-62% Fe-oxides, and variable W-oxide (0.93%-12% WO_3) (Bayhan 1984, 1986). The ore resources seem to be developed along offshoots of the Çelebi Granitoid into the marble carbonates.

Mining took place from ancient times until late 1970s. Recently, iron ore mining activities has resumed and iron ore is being mined at several localities in the district by private companies holding operation licenses and relevant permits. On the other hand, the skarns in this district are also of interest to the exploration and operation license holders and academia with the main focus being the geology and ore resources estimation of iron along with tungsten, copper and gold mineralization potential within individual skarn bodies, as well as the geochemical controls on mineralization and skarn-forming processes.

In the district, iron ore mining took place from ancient times until late 1970s. Recently, iron ore mining activities has resumed again and iron ore is being mined at several localities (in multiple open-pits) by private companies holding operation licenses and permits in the district.

The Çelebi-Kesikköprü district is located in the northwestern part of the Central Anatolian Crystalline Complex (CACC; Göncüoğlu et.al., 1991). The CACC is an assemblage of metamorphic, ophiolitic, intrusive and extrusive rocks (Fig. 4-1); those rocks exhibiting a metamorphosed platform-type succession have been termed the Central Anatolian Metamorphics (CAM) (Göncüoğlu et al. 1993). Many researchers consider CAM to be basement. CAM comprise three main rocks units consisting of gneisses at the bottom, amphibolite and marble intercalations in the middle and dolomitic marbles with amphibolite lenses at the top of the sequence. Intrusive rocks in the CACC have been collectively named the Central Anatolian Granitoids (CAG) (Göncüoğlu et.al., 1993). These rocks include granite, granodiorite, monzonite, monzodiorite, quartz monzonite and diorite. The Central Anatolian Granitoids (CAG) intrudes the metamorphic sequence and gave rise to extensive metasomatic processes between the host marbles and granitoids; the skarns are predominantly restricted to these contact zones (Kuşcu, 2001).

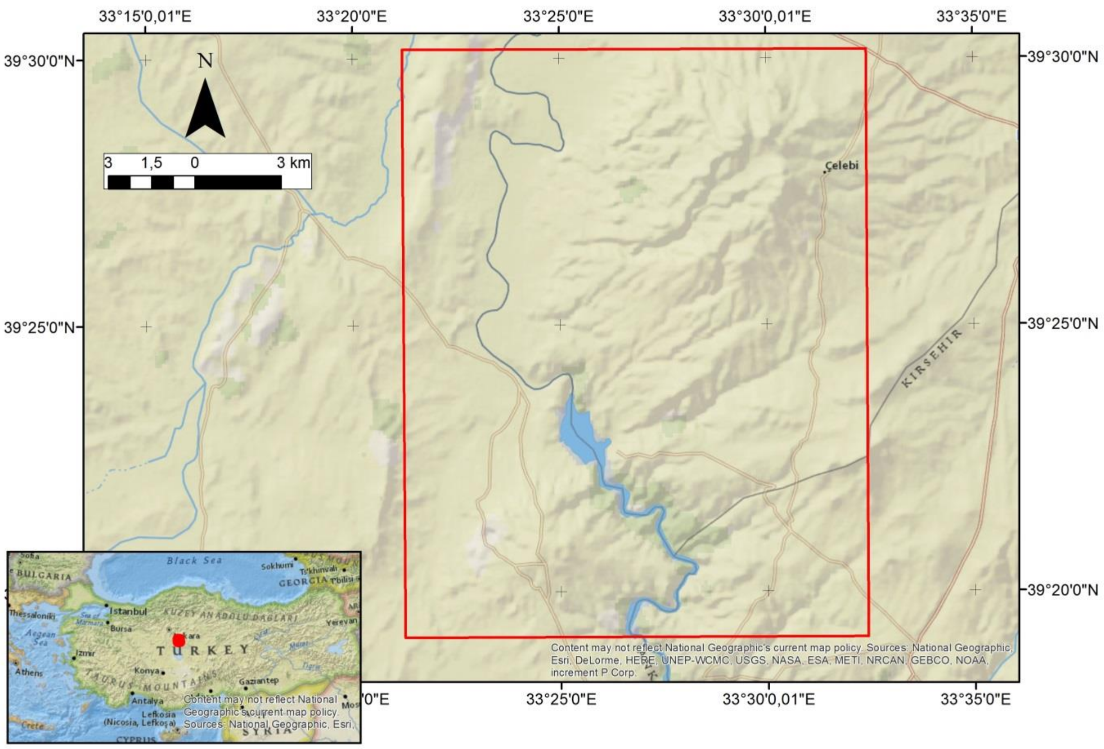


Fig. 4-1 Geographic location of the pilot mining site.

4.1.4. Description of existing data

In the district, there are a few active operating iron ore open-pit mines with relevant mining infrastructure and equipment required for extraction and enrichment. There are also many small open-pits mines that are abandoned primarily from 1970s.

The Geological Survey of Turkey have geological maps at various scales (1/100000-1/25000) and it is possible to acquire those maps from the relevant department. Accessing to other exploration and mining data could be limited. It might be possible to access some freely available and low-cost exploration and mining data from relevant government entities and/or private companies currently active in the district. For this, an agreement and/or protocol may however be required.

To our knowledge, one private company employed remotely-sensed data, primarily of optical satellite imagery data, for alteration and structural mapping purposes. Currently, no information is available whether the Geological Survey of Turkey have conducted studies in the district using Earth Observation data. Also there is no information on the possibility of accessing to any previous and present monitoring data of such as geodetic, hydrogeological, geochemistry etc.

The geological information can be viewed in web portal “GeoScience Map Viewer and Drawing Editor”, http://yerbilimleri.mta.gov.tr/anasayfa.aspx/. The portal is provided by General Directorate of Mineral Research & Exploration and the use of it is free of charge. The layers that are provided can be activated by the user by adding them to the current view. These are:
-geological formation
-landslides
-active faults
-faults
-igneous rocks
-earthquakes (last 24 H, last 7 days, last 30 days)
-index of 1/25.000 maps
-index of 1/100.000 maps
-web Mercator grid
-latitude longitude grid

On Fig. 4-2 is presented a view of geological formation present in the portal for area of interest.

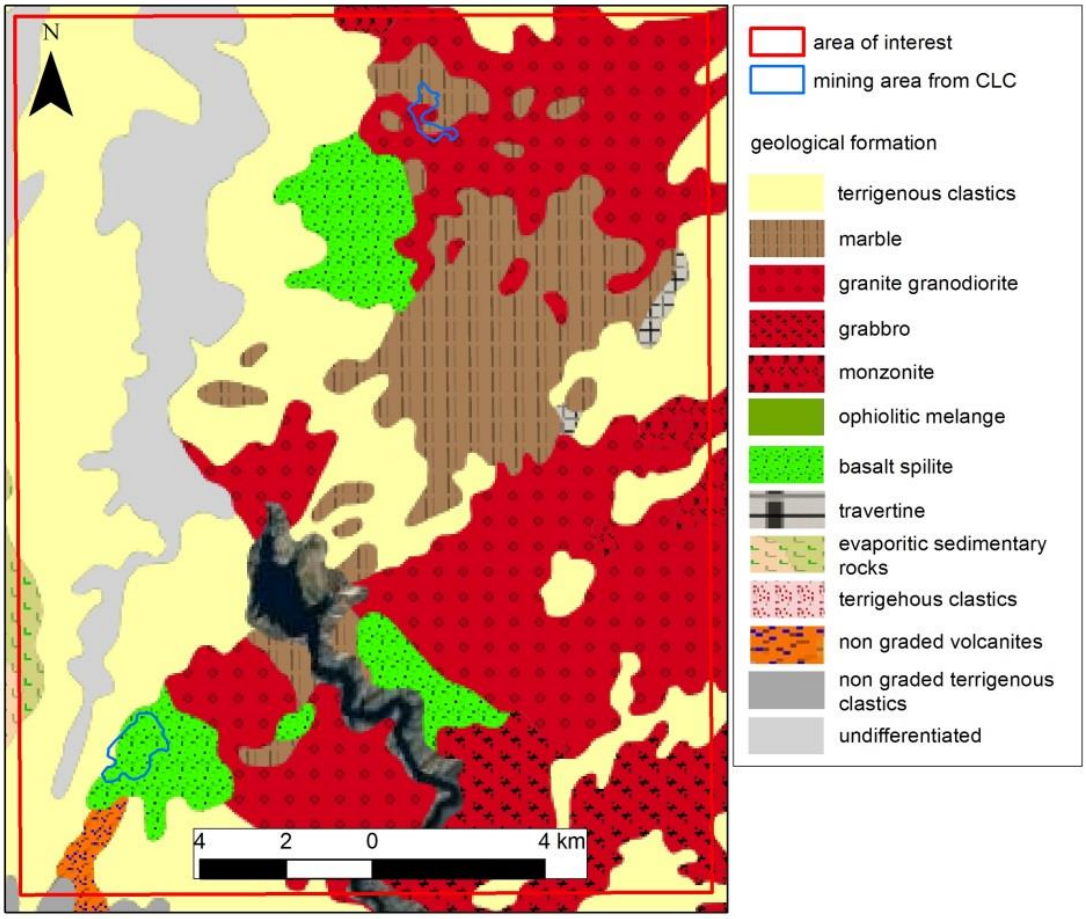


Fig. 4-2 Geological formations of area of interest from GeoScience Map Viewer and Drawing Editor.

Topographic and land cover data are available from various sources and in various formats:
DEM & land cover data have been obtained by the EU Copernicus service http://land.copernicus.eu/pan-european/. The pan-European component is coordinated by the European Environment Agency (EEA) and produces satellite image mosaics, land cover / land use (LC/LU) information in the CORINE Land Cover data, and the High Resolution Layers.
The EU DEM http://land.copernicus.eu/pan-european/satellite-derived-products/eu-dem/view/.
The CORINE Land Cover is provided for 1990, 2000, 2006 and 2012. This vector-based dataset includes 44 land cover and land use classes. The time-series also includes a land-change layer, highlighting changes in land cover and land-use. The high-resolution layers (HRL) are raster-based datasets which provides information about different land cover characteristics and is complementary to land-cover mapping (e.g. CORINE) datasets.

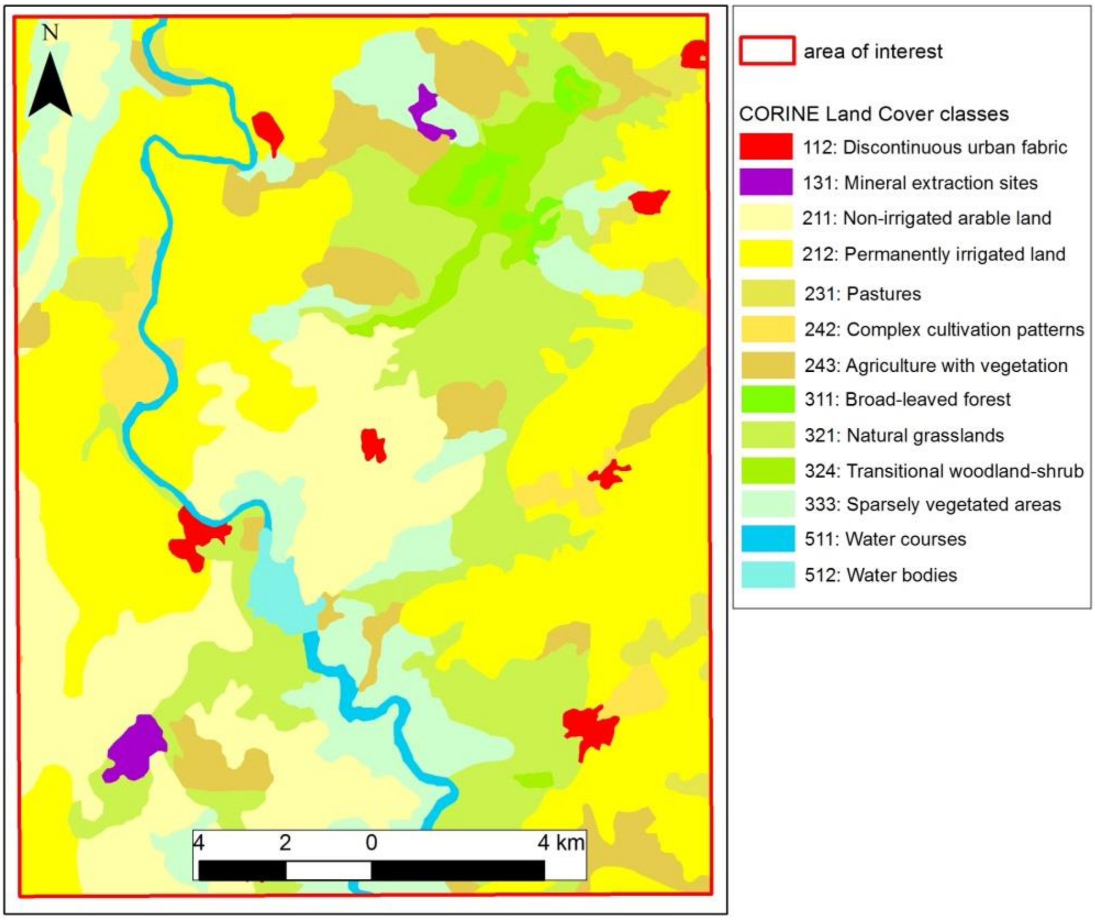


Fig. 4-3 CORINE Land cover layer for area of pilot site.

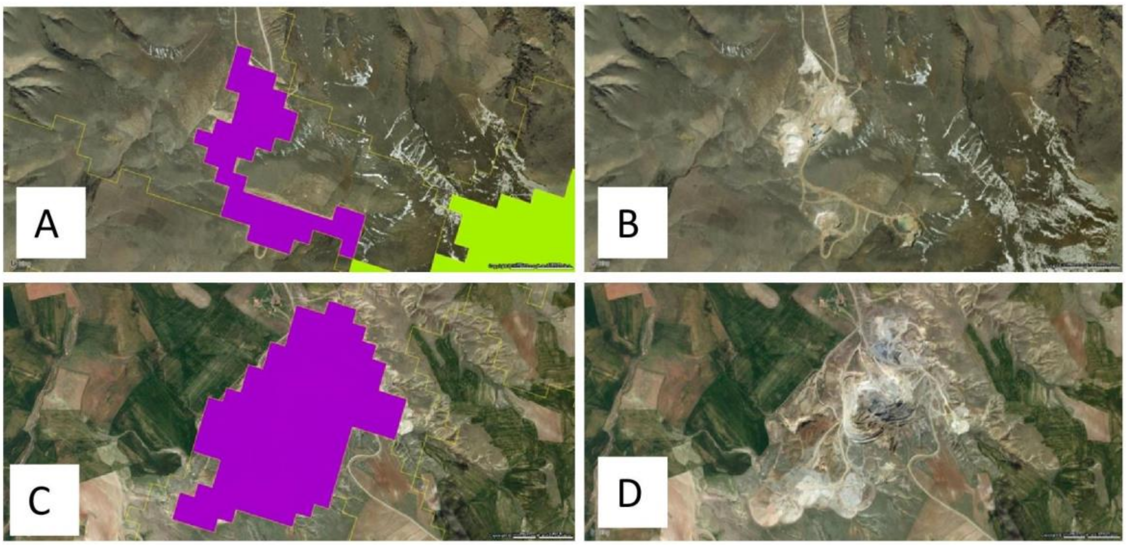


Fig. 4-4 Corine land cover LC/LU of the mining area located in the Northern part of the pilot area study (A) / Ortho Photo of the same area (B) / Mining area according to LC/LU in the Southern part of the area(C) / Ortho Photo of the same area (D)

It is shown that the mapping scale of LC/LU is too coarse for monitoring the mining areas as just the general outline of the mining areas is defined (Fig. 4-4).

It is indicated that satellite data are needed in order to establish a mapping and an up to date monitoring system for the mining areas. Sentinel 2 satellite system has been selected to be evaluated for “mapping and monitoring the mining area”. Sentinel 2 data can be used for monitoring local processes as its specifications are comparable but with enhanced features in relation to other satellite systems like the Landsat series. The data are freely available to the scientific community.

Another type of data is the Ortho-imagery provided by Bing maps, Google Earth (Fig. 4-5).

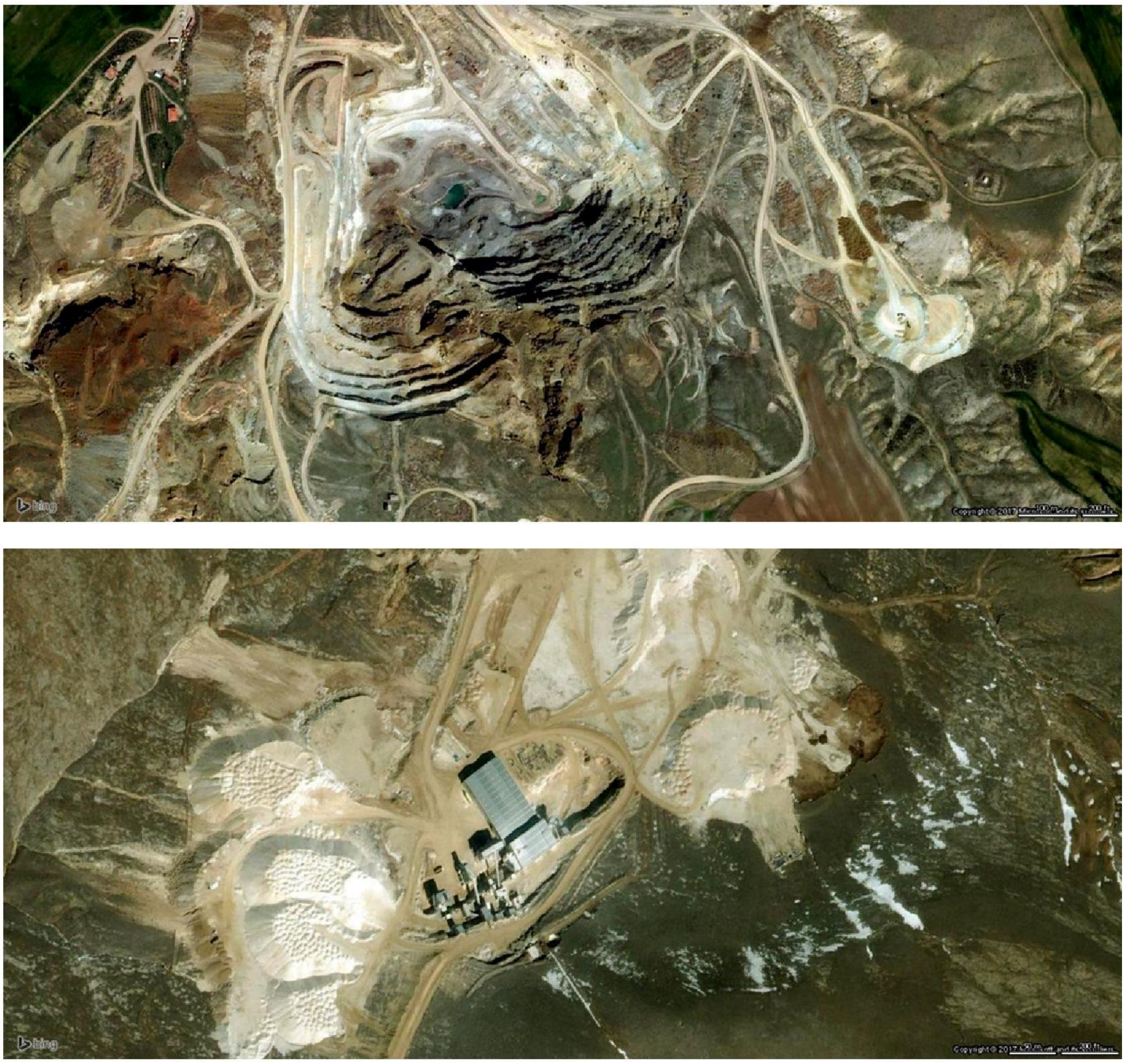


Fig. 4-5 Bing maps ortho-photos integrated within the GIS system - Google Earth can also be synchronized as an external viewer in the GIS system.

4.2. Project description

4.2.1. Objectives and expected results

Remote sensing methods have a great potential application to geological exploration for mineral resources as well as to study of environmental geology. It is worth noticing that EO methods are gradually evolving from research and experimentation into routine operation. Starting from the black-and-white aerial photographs, over the past few decades have been used in geology pictures of many different bands. If several types of imagery are obtained from an exploration area, the interpretations may reinforce each other and lend greater weight to the geologist's recommendations. In general, remote sensing should be regarded as a reconnaissance method to image large areas and to indicate promising sites for more detailed investigations. Areas that are relatively unexplored are suitable for remote sensing reconnaissance as a first step in an exploration program. In areas that have been explored in detail, the EO methods may be useful for improving the management and acquiring the additional data for waste material mapping and pollution assessment (Lintz and Simonett, 1976).

A lot of digital processing methods were developed for identifying zones with acid mine drainage, an important environmental problem posed by the mining community and caused by the oxidation-weathering of sulphides containing heavy metals. These methods could be further developed when used higher resolution optical data and hyperspectral data. Multispectral and hyperspectral images can be used for mineral mapping, the OH-FeOx anomalies and potential zones designation (for example for iron and other polymetallic mineralization). High-spatial resolution VNIR and SWIR spectral data can be employed to further differentiate and identify the presence of specific alteration minerals, often indicators of mineralization in subsurface. This in turn helps mining companies to focus on areas for further exploration (prior to expensive conventional methods such as trenching and drilling), thereby reducing fieldwork and minimizing environmental impact. An integrated structural fabric analysis from optical and SAR data may also help to narrow prospective target areas and bring down the costs for new discoveries.

Significant help to mineral mapping is also imaging spectroscopy. This tool is now widely used in mineral exploration, especially by exploration companies, which offer to their clients: data acquisition, preprocessing and product de-livery. Usually such exploration projects rely mainly on airborne imaging spectrometers such as Hymap, AISA or HySpex. However access to this data is limited and expensive and usually is not available for research purposes. The available space borne imaging spectrometer is Hyperion (Earth Observing-1 EO-1) operating since 2000. It covers the full spectral range from the visible to the shortwave infrared. New and advanced space borne imaging spectrometers such as the Environmental Mapping and Analysis Program (EnMAP) will provide new data for research in the field of imaging spectroscopy for mineral exploration (Mielke et al., 2014).

The effectiveness of remote sensing in the identification of iron oxide was proven by numerous of studies, for example: Soe et al., 2005, Feizi and Mansouri 2013, Rockwell 2013, Mielke et al., 2014b, Fernando et al., 2016.

For mineral mapping multispectral and hyperspectral imaging data have been successfully used especially to map iron oxides. Iron is a heavy, chemical active element. Native iron is rare in terrestrial rocks but fairly common in meteorites. Iron occurs in a wide range of ores in combination with others elements, e.g. hematite, goethite and magnetite. Ferriferous minerals found in ironstones include goethite, hematite, pyrite, siderite, limonite and chemosite (Soe et al., 2005). In arid regions and where the vegetation cover is low, outcropping iron oxide zones are mineralogical explicit enough to be detected successfully from spaceborne multispectral and hyperspectral data (White et al.1997, Abdelsalam et al. 2000, Farooq & Govil 2013, Feizi & Mansouri 2013). High vegetation density, however, can critically limit the successful designation of mapping iron oxide by optical remote sensing (Fernando et al., 2016).

The multispectral data can be also used for mapping mining wastes. The mineralogical components that are accumulated in mining wastes are usually anomalies of natural hydrothermal alteration and acidification. The most relevant groups being iron-oxy-hydroxides (FeOx) and OH-bearing secondary clay minerals and sulfates, frequently associated with pyrite weathering. Mapping the areas of this specific reflectance can lead to successfully map the areas of rock waste piles, tailing ponds, open-pits, where the exposed material is heavily iron-stained and frequently contains also OH-bearing secondary minerals where processes of alteration and/or acidification occur (Vijdea et al., 2004).

The pilot application in Turkey comprised the use of EO methods for geologic mapping and monitoring mining activities. A long term objective will be the establishment of a Tool, with the use of EO data, which could facilitate the competent authorities in an improved mining exploration mapping and the monitoring of related activities. This Tool may be used as a supportive mining exploration tool. In Çelebi-Kesikköprü Iron-oxide mineralization district following proposed EO methods are applicable and might be found useful by the mining industry and geological end-users:

- use of Senitnel-2 data for landscape change analysis;

In optical images, it is possible to study changes that have occurred in the mine's surroundings. Time-series analysis of these changes supports the process of managing the mine, exploitation, as well as closure and reclamation of the site.

- surfacial mineralogical mapping of mining material using time-series Landsat-TM (ETM+) images to map OH-FeOx anomalies;

The methodology described in PECOMINES project (Vijdea et al., 2004) can be applied to identification of sites, which are characterized by anomalous concentrations of both ferrooxy-hydroxides (Fe-Ox) and secondary clay minerals (OH-CL). It is based on feature-oriented principal component analysis (PCA) applied to Landsat-TM scenes. This anomalies reflect main mineralogical components that are accumulated in mining wastes.

- waste materials mapping from satellite data by determination of iron feature depth index;

Iron Feature Depth can be used for mapping the spatial distribution of secondary iron bearing minerals such as goethite, hematite and jarosite (Mielke et al., 2014).

- discrimination of iron potential zones on ASTER, Landsat ETM7+, Landsta-8/OLI and Seninel-2 satellite images;

Freely available optical data like Landsat and Seninel-2 images, as well as WorldWiev-3 high-spatial resolution VNIR and SWIR spectral data (16 spectral bands) can be employed to further differentiate and identify the presence of specific alteration minerals, often indicators of mineralization in subsurface, which in turn helps mining companies to focus on areas for further exploration (prior to expensive conventional methods such as trenching and drilling), thereby reducing fieldwork and minimizing environmental impact.

- monitoring ground displacements with InSAR (satellite radar interferometry) by Sentinel-1 data as well as integrated structural fabric analysis from optical and Sentinel-1 SAR data.

This may help to narrow prospective target areas and bring down the costs for new discoveries.

From the above mention methods, specific main objectives of the Çelebi-Kesikköprü Iron-oxide mineralization district pilot feasibility study are as follows:

- Description of possible use of Senitnel-2 data for landscape change analysis (for 2 year period).
- Discrimination and mapping of iron potential zones using Landsat-8/OLI, Seninel-2 satellite imagery data.

4.2.2. Methodology, methods of implementation

1. Senitnel-2 data for landscape change analysis

Environmental monitoring is now an integral part of mining operations. Remote sensing enables the identification, delineation, and monitoring of mining areas, including derelict land, and changes in surface land use, (See References). The aim of this pilot site is to evaluate the use of Earth Observation and in particular of the multi-temporal Sentinel 2 data to map and monitor "Fe mines" on a local scale, and to assess the contribution of Sentinel 2 data on mapping land cover / geologic features of interest to the End User. The general Plan of the methodology applied for this Pilot Site is shown in Fig. 4-6 and it includes:

- Mapping and monitoring (Change analysis / track any detectable potential changes of surface morphology) based on satellite Sentinel-2 data.
- Evaluation of the contribution of Earth Observation data on supporting studies of geological mapping / mineral exploration and the monitoring of Fe mining sites. Fig. 4-6 shows the overall plan of the Sentinel 2 monitoring system of the pilot project area.

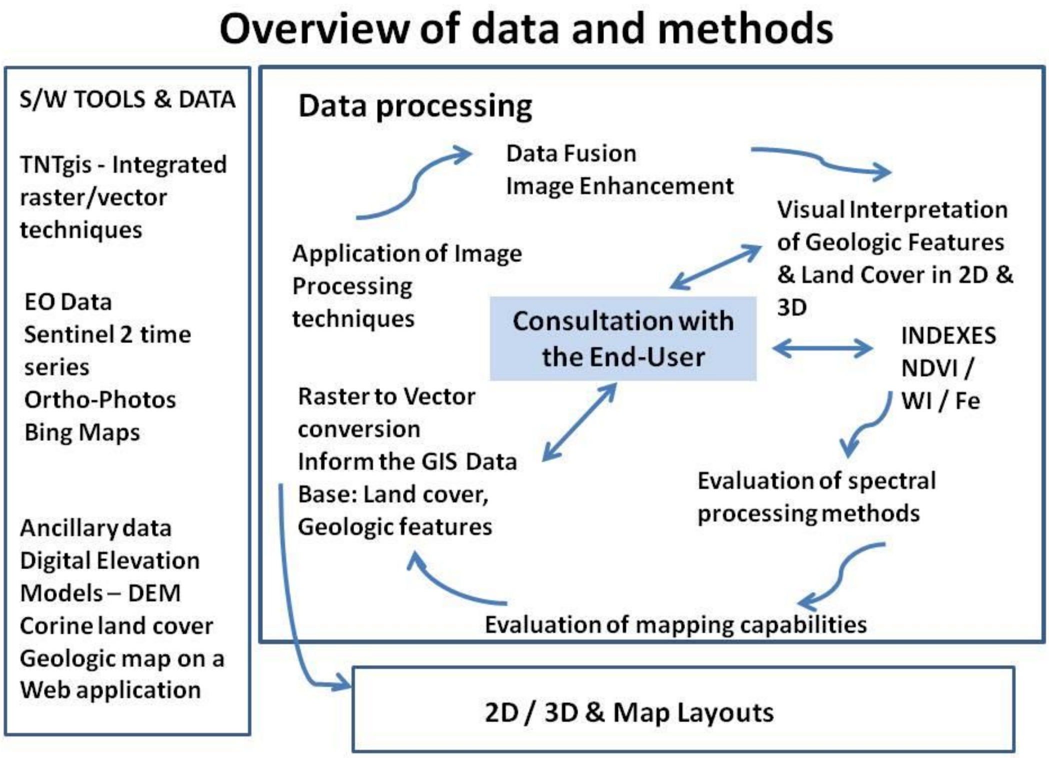


Fig. 4-6 Overview of overall plan of "Data and Processing techniques" applied in Iron Mining Area of Turkey

2. Designation of iron potential zones on Landsta-8/OLI, Seninel-2 satellite images

The methodology for regional designation of iron-bearing minerals potential zones takes advantage of the spectral characteristics of the minerals. To detect iron oxide minerals in image data spectral properties (reflectance and absorption of specific electromagnetic wave length) were exploit. The specific characteristics of spectral reflection curve of selected minerals were taken from United States Geological Survey (USGS) spectral library (https://speclab.cr.usgs.gov/spectral-lib.html). The analyzes were done for Landsat-8 and Seninel-2 multispectral images and they included calculation of several iron indexes and principal component analysis.

Iron detection by band ratio

Selected band ratios (indexes), which highlight variation in reflectance between wavelength regions measured by the various bands of the satellite sensor have been calculated. This allowed to map potential iron zones and selected minerals over whole pilot site area. The chosen indexes usually successfully identify mineral groups, however suitable scenes should include minimum cloud, haze, dust, smoke and snow cover and maximum solar illumination (high solar elevation angle during late spring or early autumn).

The indexes involved usage of compound band ratios to identify area where one or more specific spectral absorption features are present. Ratios were developed by series of previous studies, e.g. Soe et al., 2005, Feizi and Mansouri 2013, Rockwell 2013, Mielke et al., 2014b, Fernando et al., 2016.

The calculations assume that only a particular mineral group will have deep absorption at a particular wavelength interval (spectral band). If another surface material has deep absorption at a given band a false detection of a mineral group will occur. Therefore in most of the cases the utility of the ratio type (band x + band y)/ band z was applied, which identifies the absorption at band z relative to adjacent bands x and y (Rockwell, 2013).

Selected ratios (Tab. 3) indicate ferric silicates, iron oxide, ferric iron, ferric oxides, gossan were calculated from bottom of the atmosphere reflectance data. Additionally NDVI index was calculated to identify vegetation cover.

Tab. 3 Selected ratios that indicate ferric silicates, iron oxide, ferric iron, ferric oxides, gossan and NDVI indexes. The naming convention used in the formulas refer to the spectral bands of the sensor.

No.	Index name	Formula
1	Ferric iron (normalized)	$\frac{(SWIR2-NIR)}{(SWIR2+NIR)}+\frac{(RED-GREEN)}{(RED+GREEN)}$
2	Ferric oxides (normalized)	$\frac{(SWIR1-NIR)}{(SWIR1+NIR)}$
3	Ferric silicates (normalized)	$\frac{(SWIR2-NIR)}{(SWIR2+NIR)}$
4	Gossan (normalized)	$\frac{(SWIR1-RED)}{(SWIR1+RED)}$
5	Iron oxides (normalized)	$\frac{(RED-BLUE)}{(RED+BLUE)}$
6	NDVI	$\frac{(NIR-RED)}{(NIR+RED)}$

Iron oxides have wide absorptions caused by electronic processes: crystal field and charge transfer absorptions in NIR channel (Singer, 1981). Goethite and hematite have characteristic absorptions in 0.63 – 0.71 and 0.85 – 1.00 μm, respectively, and an absorption feature between 0.48 and 0.55 μm (Morris et al. 1985). High values in band ratio RED/BLUE are useful to detect the absorption related to iron oxides in the blue spectral region. The ratio is sensitive to ferric iron even in low concentrations. High values of band ratio (SWIR2/NIR) + (RED/GREEN) are useful to detect the crystal-field absorption of ferric iron oxide (Rockwell 2013). The results of this band ratio highlighted mainly the high-grade iron ore. Band ratio SWIR1/RED is commonly used for its ability to map gossan. However, vegetation spectra also have a high reflectance on band SWIR1 and low reflectance in band RED. Consequently, the ratio enhances not only gossan but also vegetation. NDVI index allow to highlights areas of green vegetation with abundant chlorophyll content. NDVI is a standardized vegetation index, which generates an image showing an estimation of biomass (Rockwell, 2013, Fernando et al., 2016).

Iron detection by Principal Components Analysis (PCA)

Principal component analysis (PCA) is an image processing technique that has been commonly applied to satellite multispectral images to locate iron oxide minerals. This technique indicates whether the minerals are represented bright or dark pixels in the principal components according with the magnitude and sign of the eigenvectors loadings (Soe et al., 2005).

PCA is based on linear transformation of the original coordinate axes of the data (multispectral vector space), into a new vector space where the axes are uncorrelated. Therefore the covariance matrix in the new coordinate system is diagonal, having all elements equal to zero, except the first diagonal, where the elements (i.e. the variances of the data in the transformed coordinates) are in decreasing order. These variances of the data in the transformed multispectral vector space (or principal components) are the eigenvalues of the covariance matrix (Vijdea et al., 2004). In other word the PCA is a multivariate statistical technique that selects uncorrelated linear combinations (eigenvectors loadings) of variables. Each successively extracted linear combination, or principal component (PC), has smaller variance (Myint et al., 2005).

For designation of specific minerals, examination of eigenvector loadings in each PC image is used for determining which image contains information related to the spectral reflectance of specific mineral. The PC image that is characteristic by high eigenvector loadings for the absorptive or reflective bands of the mineral spectral reflectance could be considered as the specific image for that mineral. If the loading of absorptive band is negative in sign, the target area will be shown in bright pixels, and if the loading of reflective band is negative, the area will be shown in dark pixels (Crosta and Moore, 1990, Khaleghi and Ranjbar, 2011).

For designation iron potential zones PCA was performed with BLUE, RED, NIR and SWIR1 spectral channels of Landsta-8 and Seninel-2 data. The analysis of eigenvector loading revealed that iron-earing pixels should be enhanced in bright color in PC 3 and in dark color in PC 4.

4.2.3. Main activities

1. Senitnel-2 data for landscape change analysis

Initial processing for change analysis and monitoring is based mainly on satellite Sentinel-2 data using time series data for the period of 2015 and 2017 for the pilot project area.

The basic S/W tool used for the integrated analysis of both raster and vector data is the TNTgis software. Research has been accomplished following step by step analysis including (1) Pre-processing of EO data, (2) Image processing, (3) Evaluation of classification techniques, (4) Application of GIS techniques, (5) Evaluation of techniques for the distribution of processed information. Consultation with the End User has been carried out so as to identify its needs.

Various image processing and vector GIS techniques are used for the analysis of the satellite imagery and the collected map data.

Pre-processing

Identification of areas of interest with respect to mining areas as this has been identified by the End User. Acquisition of multi-temporal data has been carried out for the area for the years 2015, 2016 and 2017. Application of atmospheric correction techniques. Resampling was carried out using the bi-cubic method.

Image Processing

Colour composites: Various pseudo-colour composites like the RGB-843 have been used of the Sentinel 2 data in order to emphasize the mining areas, which have high spectral reflectance. The composites accentuated the mining areas and discriminated vegetation from barren soil.

Intensity hue saturation (IHS) images: different resolution data were combined using data fusion techniques. This was effective for the land cover and the interpretation of geologic features because complementary information for the same target area was combined. The IHS transform was used to fuse the bands of higher panchromatic spatial resolution with the multispectral bands of the Sentinel 2 so that the inherent land cover classes in the mining areas could be identified. PCA has been applied of the bands with higher resolution for data noise reduction, while PC1 component has been used as the panchromatic image -PAN in the data fusion process. Final image products derived from this procedure was the 8,4,3-PAN and similar RGB-PAN composites.

NDVI calculation for vegetation and masking, Different Fe related indexes have been also calculated.

Map layouts in 2D or 3D formats and as Stereoscopic images using the available Digital elevation Model of Copernicus.

Classification

Image Classification Unsupervised classification techniques using neural networks: Artificial Neural Networks (ANNs) are generally quite effective for the classification of remotely sensed data (Vassilas and Charou 1999). For classification purposes, the SOM- Self Organizing Map ANN method was used on the Sentinel-2 images in order to discriminate all inherent land cover classes of the satellite images. Different land cover types were mapped in the quarry areas and the surface extent for each cover type was estimated.

Automated combination of the classification result of multi-temporal imagery: Automated conversion of raster to vector data: the raster output of the classification and/or interpretation process was converted to vector data and these data can be analysed with the corresponding map data and observation acquired on the Ortho-images.

Processing and analysis: further processing and analysis can be performed to derive information concerning changes identified in pilot study areas.

Discrimination of geologic setting

A short visual evaluation of the geologic information provided by the Geoscience Map Viewer has been included. As it is shown on the Fig. 4-7 more "geologic information" is shown on the processed Sentinel-2 image (B) than the geologic map of the Map Viewer (A), Fig. 4-7.

Fig. 4-7 Synchronized views of the ~ same area as shown (left) on the Geoscientific Viewer and the GIS - enhanced and annotated Sentinel 2 image (right).

GIS techniques

Collection, input, coding, storage, management, retrieval of various data: all ancillary data (raster, vector) selected in this study are aggregated in the GIS in order to assess mining exploration activities. Extraction of the topographic variables (shading relief, slope & aspect) have also applied.

Dissemination of information

It is anticipated that there is a need to disseminate information of collected and processed Earth Observation and GIS data using electronic means (free software) which are to be dedicated to cover the End User needs. This need is further enhanced as processed data have to be delivered in full spatial / spectral and temporal resolution.

The processing has followed specific steps as shown in Fig. 4-6.

2. Discrimination and mapping of iron potential zones on Landsat-8/OLI, Seninel-2 satellite imagery data

Data analysis of multispectral optical satellites should start with the selection of the best scenes from the period of interest. Landsat-8/OLI satellite images can be pre-viewed and download form USGS Earth Explorer web-portal https://earthexplorer.usgs.gov/, whereas Seninel-2 can be pre-viewed and download from ESA Sentinel Data Hub https://scihub.copernicus.eu/dhus/#/home. The search parameters allow for selecting desire date and location. Preview options helps to estimate if the cloud covered is low enough. The appropriate scenes should be acquired with maximum solar illumination (high solar elevation angle during late spring or early autumn).

Chosen images should be pre-processed. This stage should include geometric, radiometric and atmospheric correction. If it was not possible to find scenes without cloud cover, it is necessary to mask the cloud areas.

After choosing the selected spectral bands as separate rasters, iron indexes calculation can be performed in special remote-sensing software (e.g. ENVI) or simply in GIS environment by raster calculator. Similarly Principal Component Analysis can be performed in dedicated software or GIS program. After calculation of eigenvectors magnitude and sign of eigenvectors loadings in the characteristic bands should be examined and the PC which refers to the strong reflectance of absorption in the given band should be selected. In the example processing two components (PC4 and PC3) were necessary for obtaining the final image highlighting iron oxides.

The resulting images of indexes and PCA calculation should be confront with other relevant data sets (land cover, mining data of other registries or databases): e.g.: topography, Corine Land Cover, site specific information provided by the national institutions, mining site identification and location, geological maps, information/data about mineral exploitation and waste management, administrative boundaries, soil type, etc.

4.2.4. Results of the pilot site analysis

1. Sentinel-2 data for landscape change analysis

Preliminary results:

- Monitoring is supported through change analysis
- Temporal resolution of Sentinel-2 data cover needs as far as regional mapping / monitoring is concerned. Regular updates of related to different parameters can be obtained (Seasonal / monthly or even more frequently)
- Spatial resolution of Sentinel-2 data suffice covers for the needs of “regional mapping and monitoring” of mining areas and the surrounding regions.
- EO tools assist in mapping & monitoring surface activity –Aspects of the activities have to field verified by the End User.

Example of the Seninel-2 potential for the area are shown in Fig. 4-8 – 4-11.

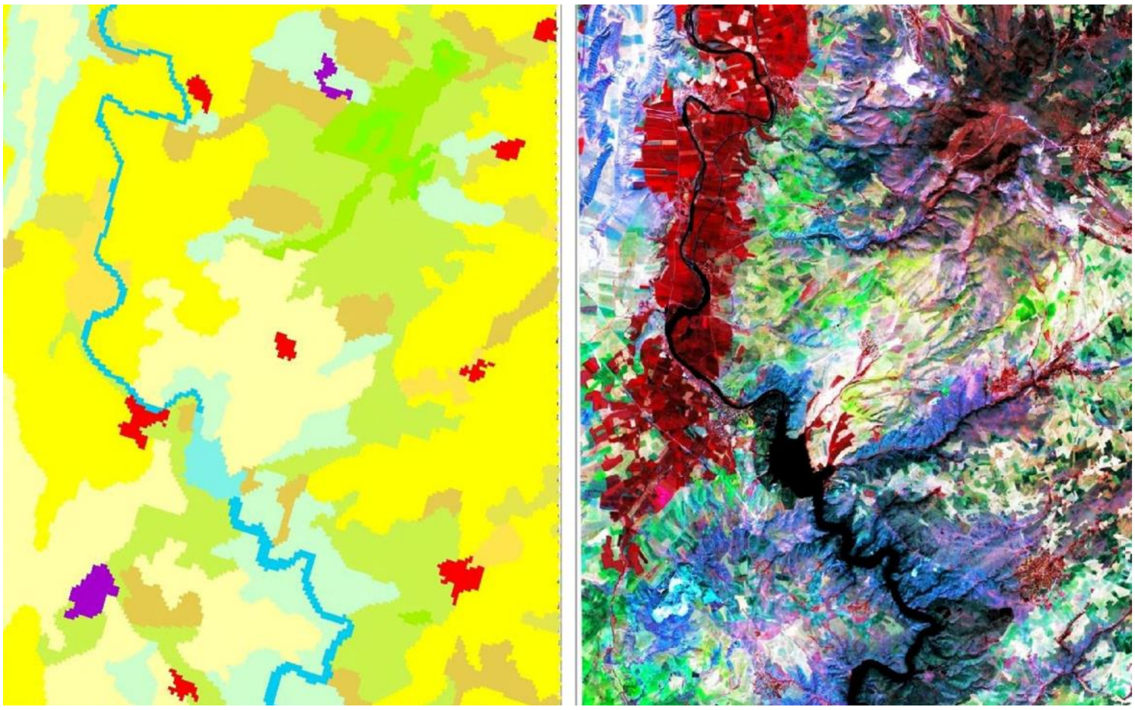


Fig. 4-8 Seninel-2 RGB (right) composition may allow Corrine Land Cover (left) update.

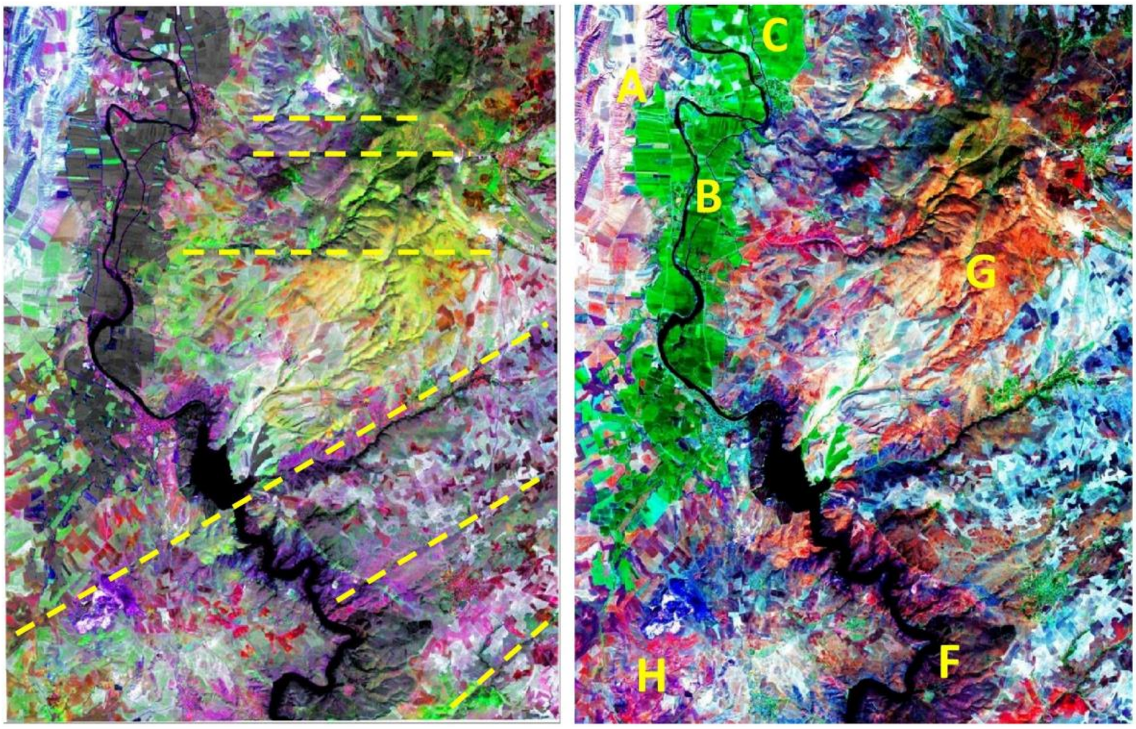


Fig. 4-9 Seninel-2 RGB composition can be helpful in discrimination of geological settings, major tectonic discontinuities and structural features. On the right figure A to G different types of lithology can be discriminated.

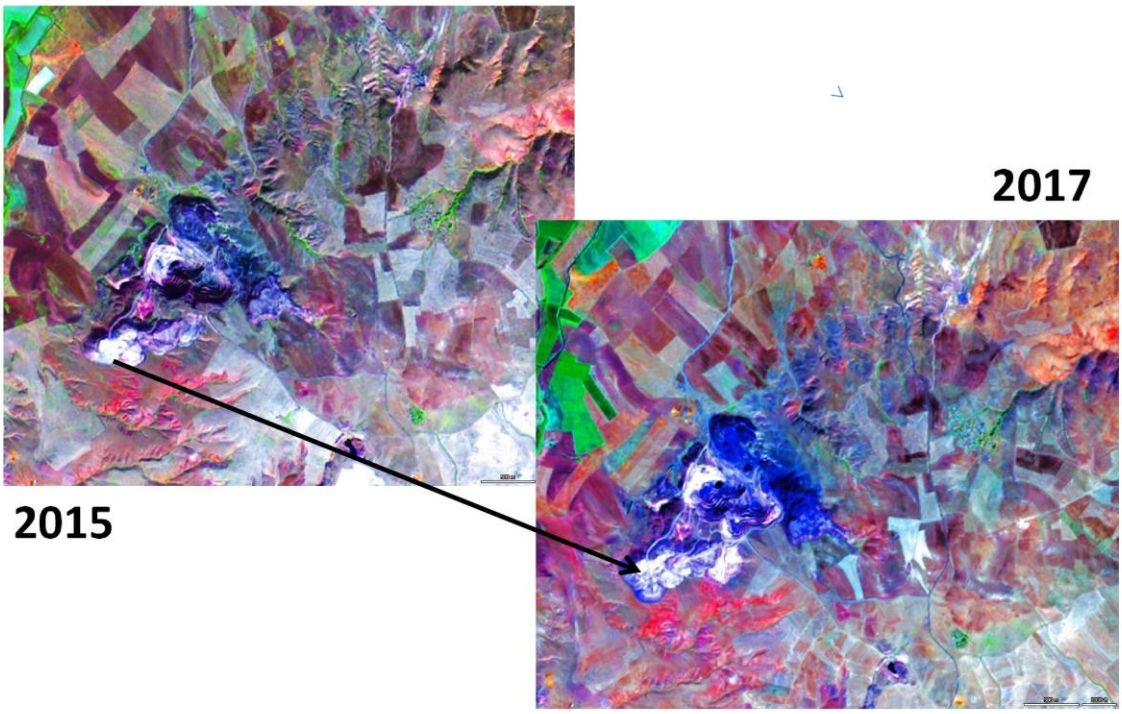


Fig. 4-10 Seninel-2 supports multi-temporal mapping of changes in the landscape. In the figure example of the changes seen in the southern part of the area of interest.

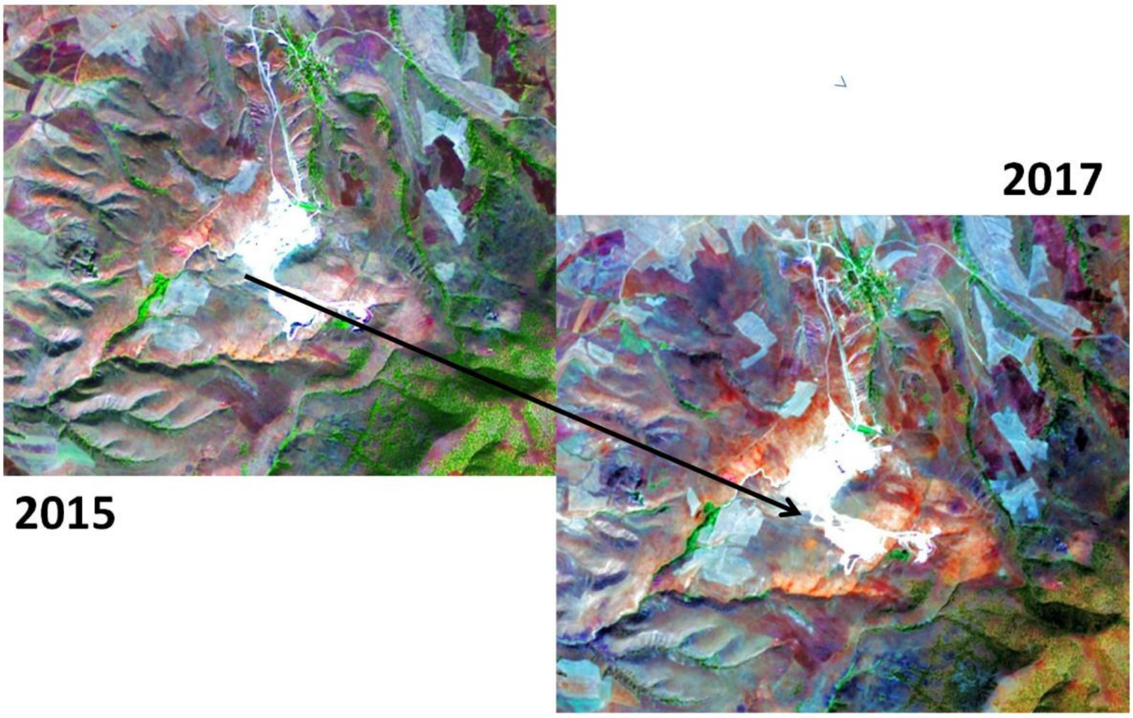


Fig. 4-11 Seninel-2 supports multi-temporal mapping of changes in the landscape. In the figure example of the changes seen in the northern part of the area of interest.

Identification of Environmental Pollution

It is indicated that the developed methodology cannot only support the monitoring activities of the mining areas, but it can also support the poly parametric analysis of different data layers for the identification of problem areas – i.e. the identification of specific areas where there might be environmental pollution problems.

Dissemination of information

Spatial information can be made available to all staff members working in the mining areas in an easily used form of an atlas-like manner. Computer users who have little training can then easily access and use the geospatial information.

Benefits

In general the immediate benefits to the End User are as following:

- Mining Site mapping - Mapping Disturbed / undisturbed land - Land use / cover changes - Delineation of areas where potential restoration activities may take place.
- Track changes of the activities which are implemented through the comparison of multi-temporal images.

- Identification and characterization of the nature of the changes observed - Compliance with permitting regulations.
- Documentation of the conditions of lands related to mining areas.
- Reclamation monitoring.
- Discrimination of geologic setting - Geologic feature extraction to optimize field reconnaissance.
- This is of particular interest to the End User as the geo-tectonic environment needs to be mapped in detail.
- Planning exploration activities in other areas in Turkey - Managing mining activities.
- GIS database creation - Visualization by the Staff and the Public.

It has to be noted that the pilot project work has been accomplished in very strict time limits (involvement for the last three months of 2017) and budget (no additional Earth Observation data could be acquired / no field visits or meetings / no expenses / etc). The action had to be based on freely available data.

2. Identification of iron potential zones using Landsat-8/OLI, Seninel-2 satellite images

For the test processing the Seninel-2 images was chosen from 4th and 14th of October 2017. Additional several indexes were also calculated for Landsat-8/OLI image from 1st September 2015 and 21st October 2016. All chosen scenes were bottom of atmosphere reflectance and cloud-free or almost cloud-free. The pre-processing and the index calculation was performed in ENVI v5.1 software with support of ArcGIS v 10.2 GIS environment.

The analysis step started with the pre-processing steps as described in the methodology section. A simple RGB natural color composite (Fig. 4-12) and a NDVI index was constructed (Fig. 4-13). Both of these images, as well as CORINE Land cover layer (Fig. 4-3) suggest that the study area is potentially promising for EO iron-indexes analysis, as the vegetation cover is not dense and the sun illumination is high.

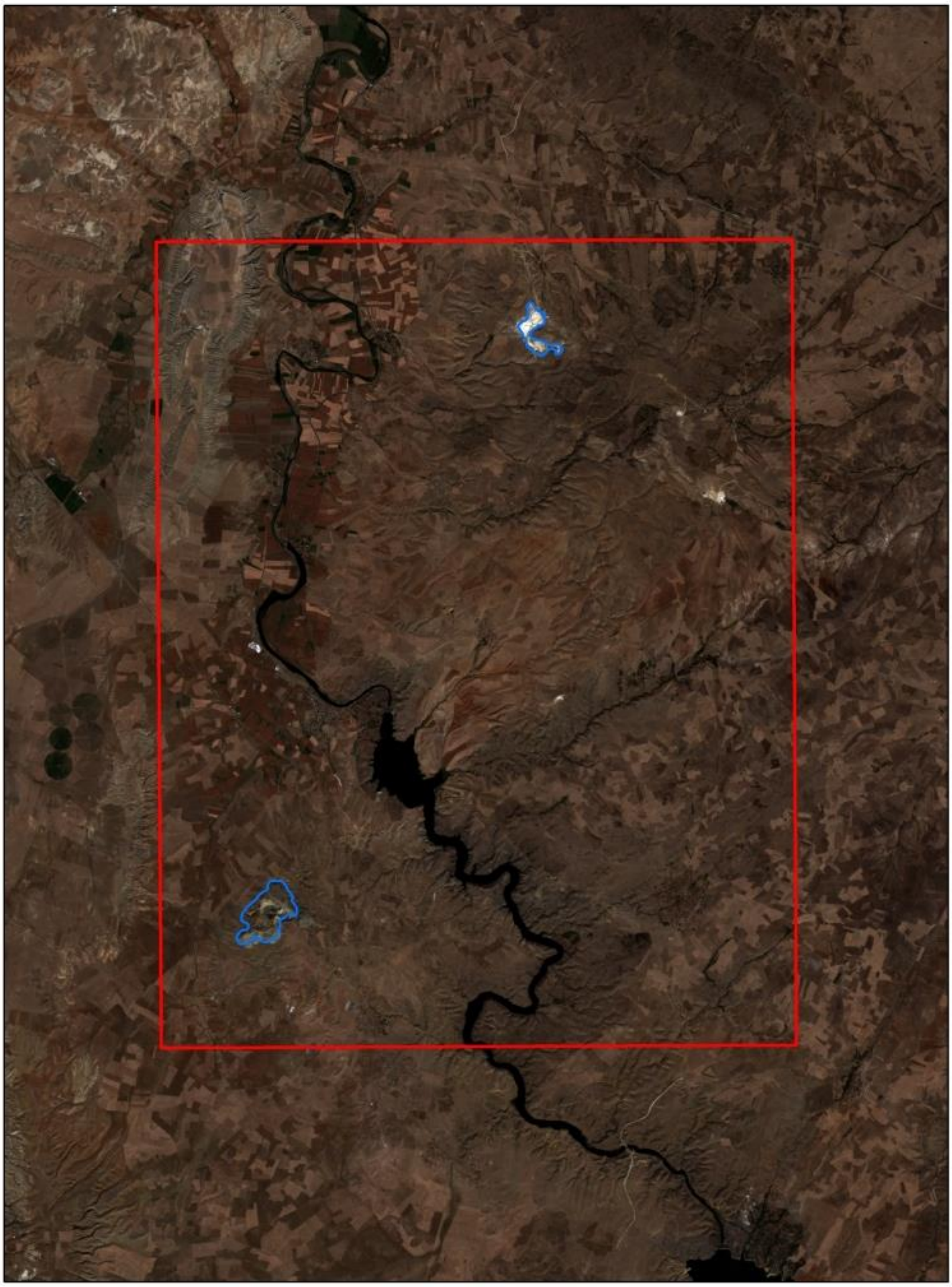


Fig. 4-12 Natural Color Composition (RGB 432) of Seninel-2 image from 4th of October 2017. In red square the area of interest. In blue polygons the mining areas distinguished in CLC layer.

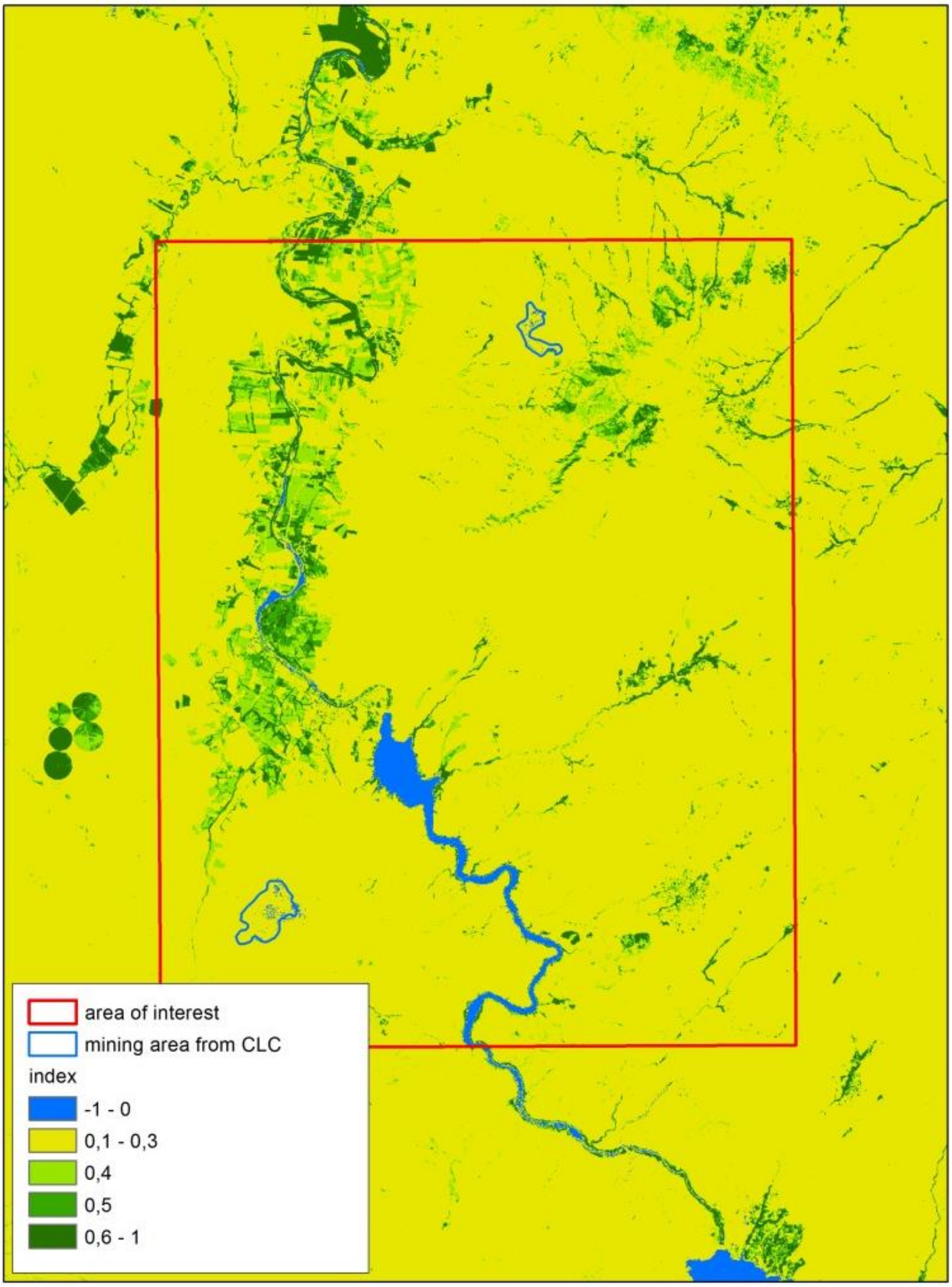
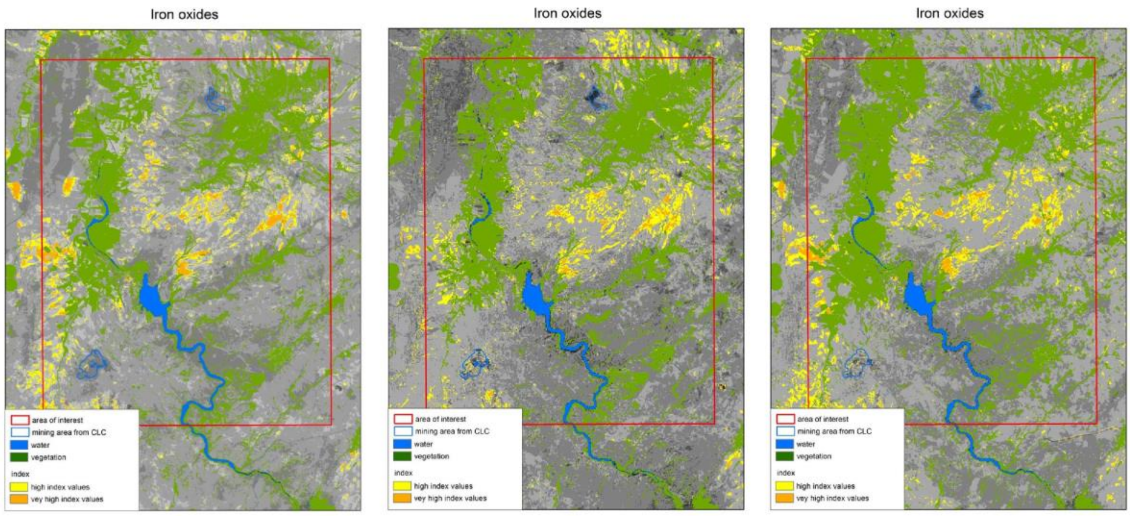


Fig. 4-13 NDVI index from Seninel-2 image from 4th of October 2017.

Further on all the indexes listed in Tab. 3 were calculated using the build-in functions in ENVI or the raster calculator in ArcGIS. On below figures (Fig. 4-14 – 4-19) are shown some of the results of the indexes calculations.

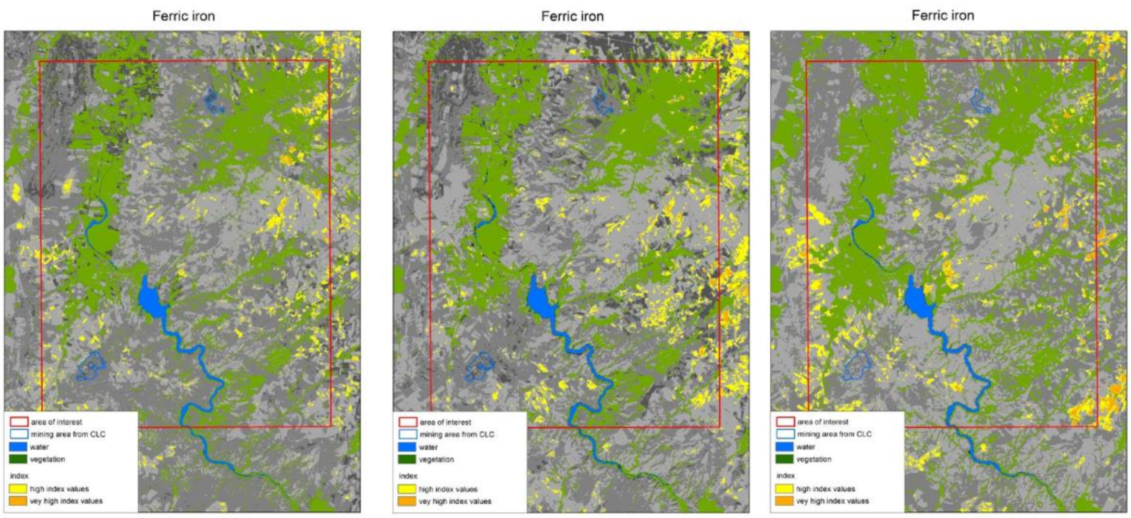


Sentinel-2
2017/10/14

Landsat-8
2016/10/21

Landsat-8
2015/09/01

Fig. 4-14 Iron Oxide index based on the Seninel-2 and Landsat-8 images. This band ratio highlights hydrothermally alerted rocks that have been subjected to oxidation of iron-bearing sulphides.

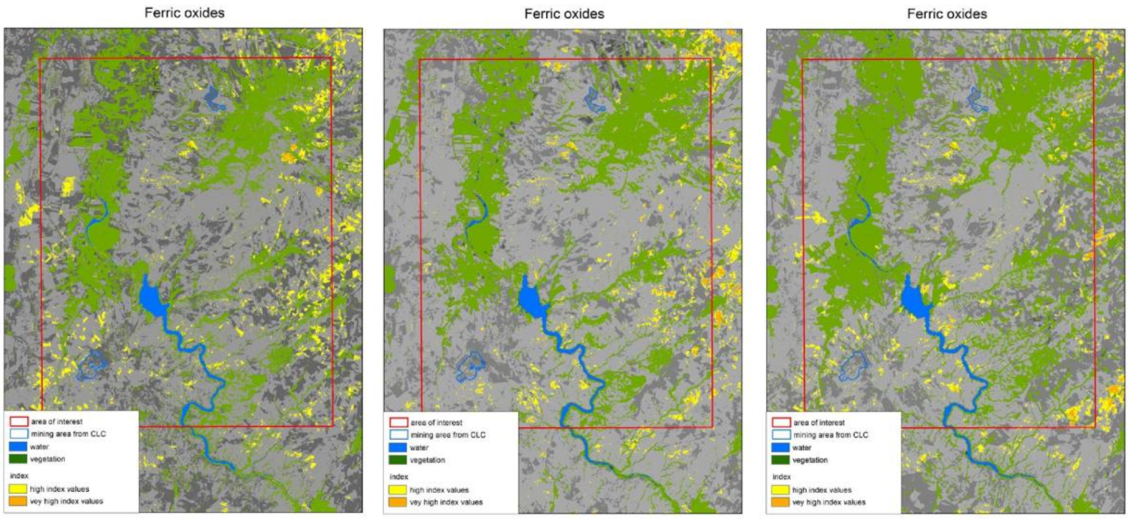


Sentinel-2
2017/10/14

Landsat-8
2016/10/21

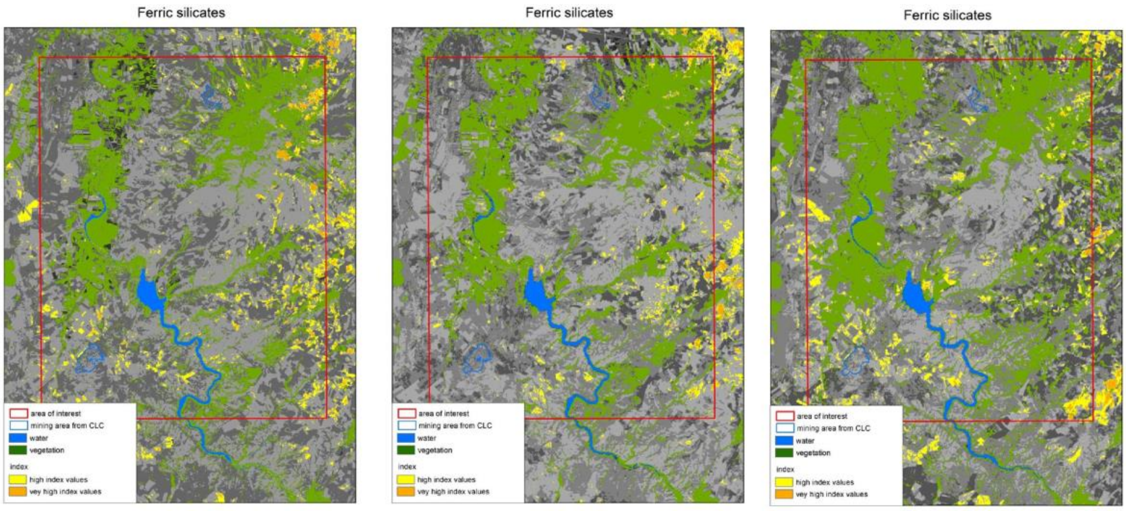
Landsat-8
2015/09/01

Fig. 4-15 Ferric iron index on three different satellite scenes.



Sentinel-2 2017/10/14 | Landsat-8 2016/10/21 | Landsat-8 2015/09/01

Fig. 4-16 Ferric oxides index on three different satellite scenes.



Sentinel-2 2017/10/14 | Landsat-8 2016/10/21 | Landsat-8 2015/09/01

Fig. 4-17 Ferric silicates index on three different satellite scenes.

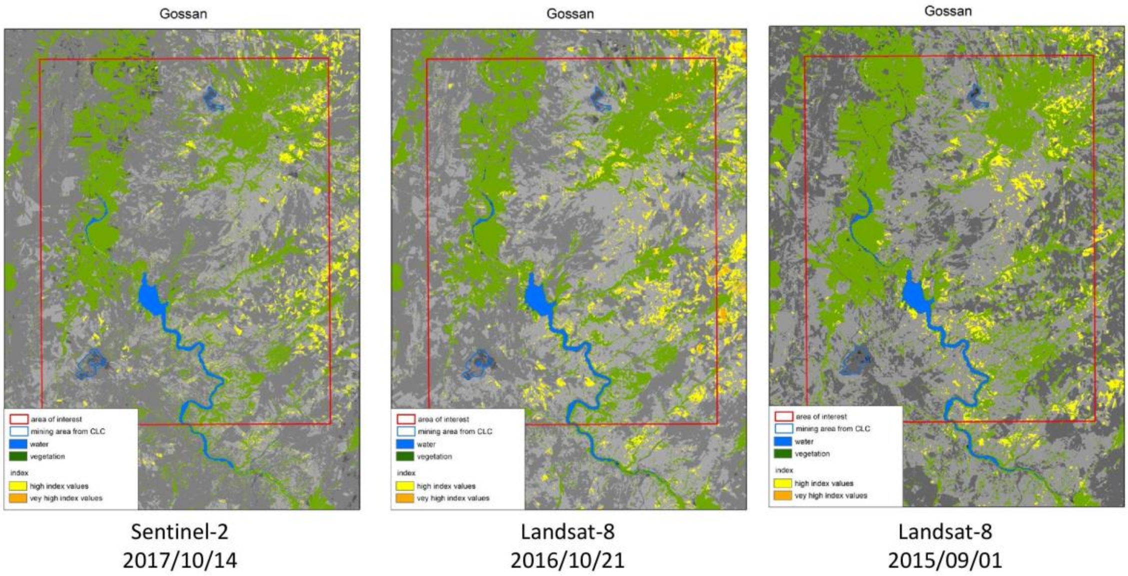


Fig. 4-18 Gossan on three different satellite scenes.

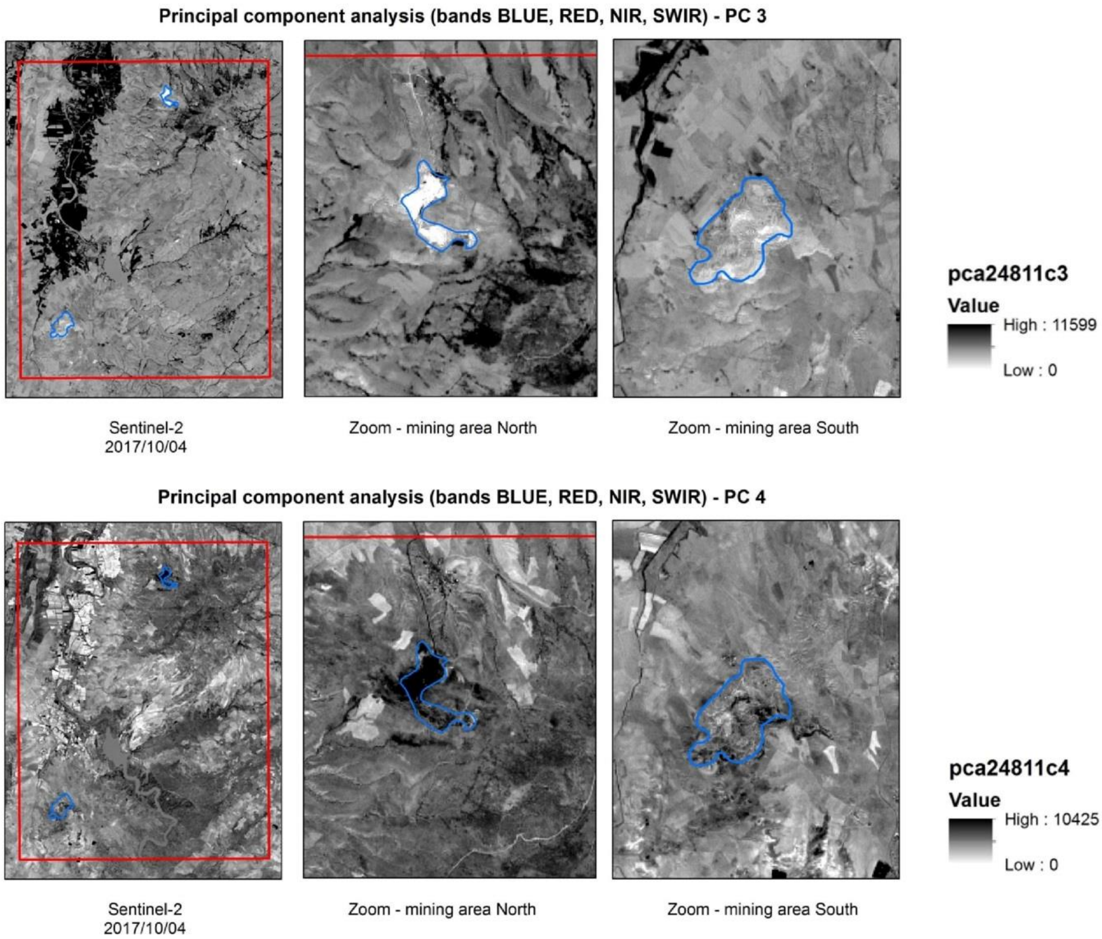
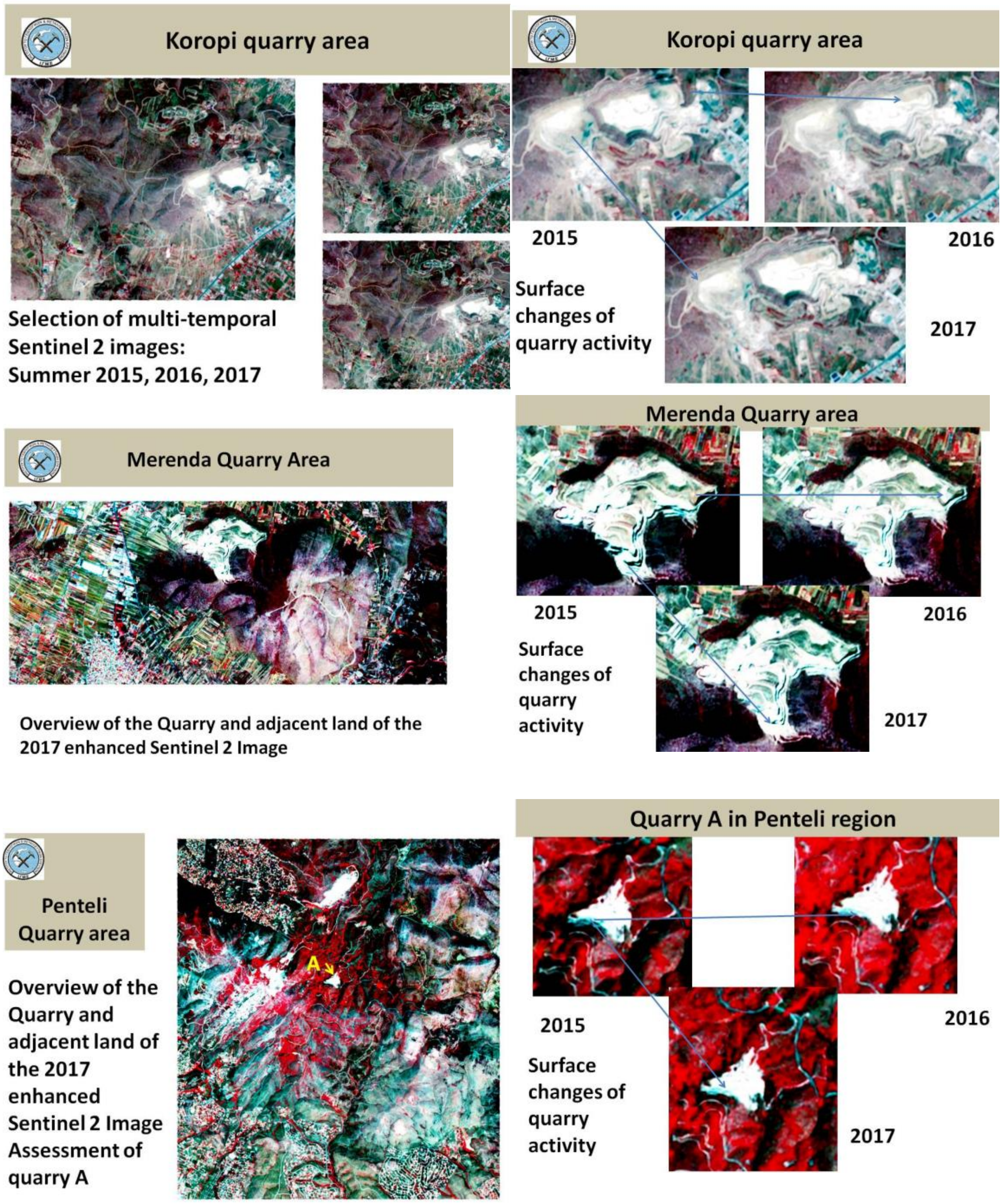


Fig. 4-19 Results of PCA of Sentinel-2 scene form 4/10/2017. Iron pixels should have values bright in PC3 (top) and dark in PC4 (below).

5. Consultations with the End-User

5.1. Greece

Consultation with the End-User for the quarries of Attica region: After the application of image processing techniques, consultation with the End User has taken place. Consultation included visual evaluation of processed Landsat and Sentinel 2 time series data. The visual assessment of surface changes of all quarries in Attica region & Cephalonia island by the End User has taken place. Results are shown on Fig. 5-1.



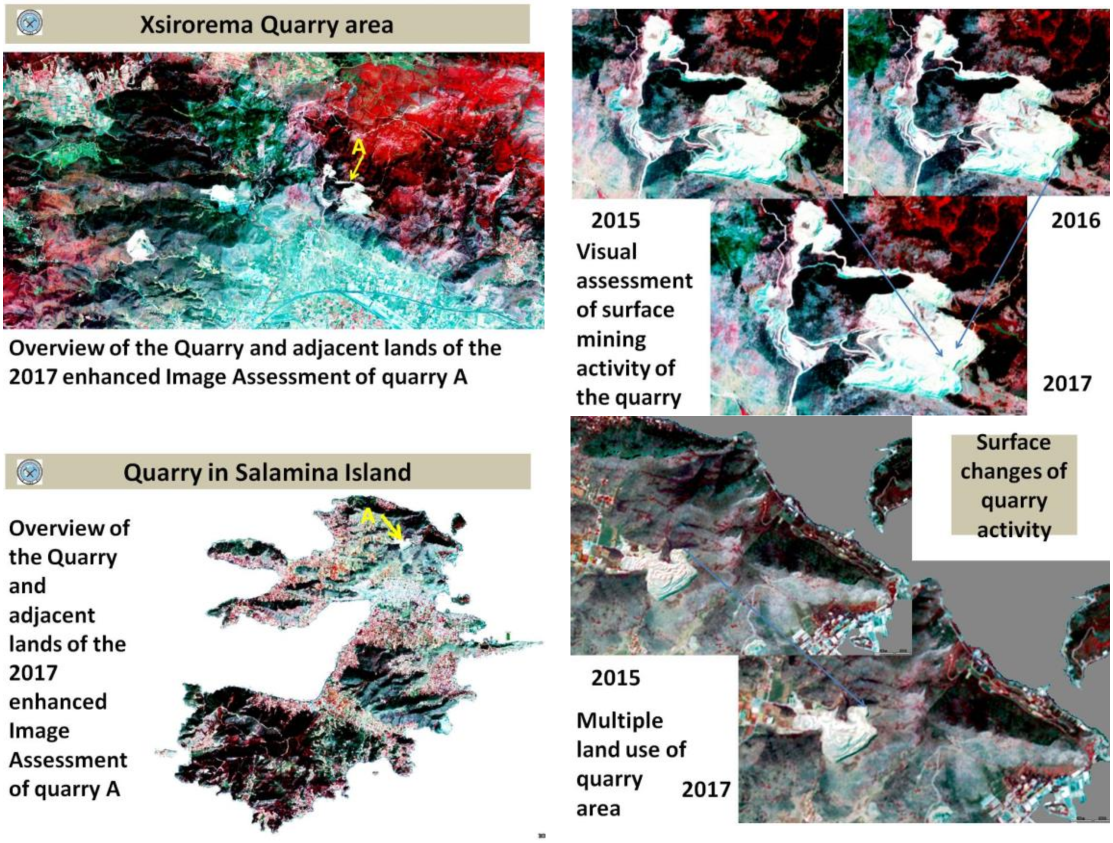
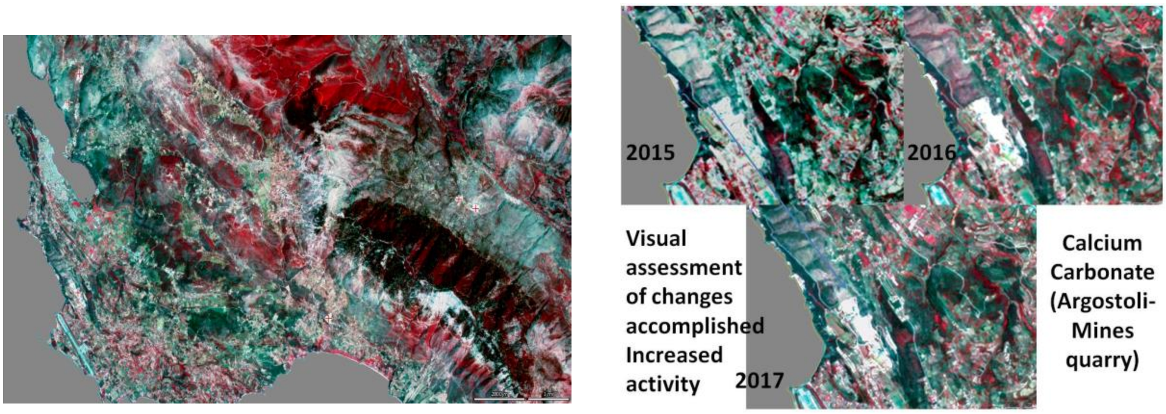


Fig. 5-1 Consultation with the End-User: Visual evaluation of processed images in relation to quarry areas of Attiki region.

Consultation with the End-User Cephalonia island: All quarry areas as they have been mapped on the IGME 2009 report have been evaluated. Visual evaluation of enhanced images in relation to quarry areas of Cephalonia island has been also carried out. The evaluation included two different satellite systems: Landsat time series data for the period 1984 to 2011 and Sentinel 2 multi-temporal images for the years of 2015, 2016 and 2017. Results are shown in Fig. 5-2.



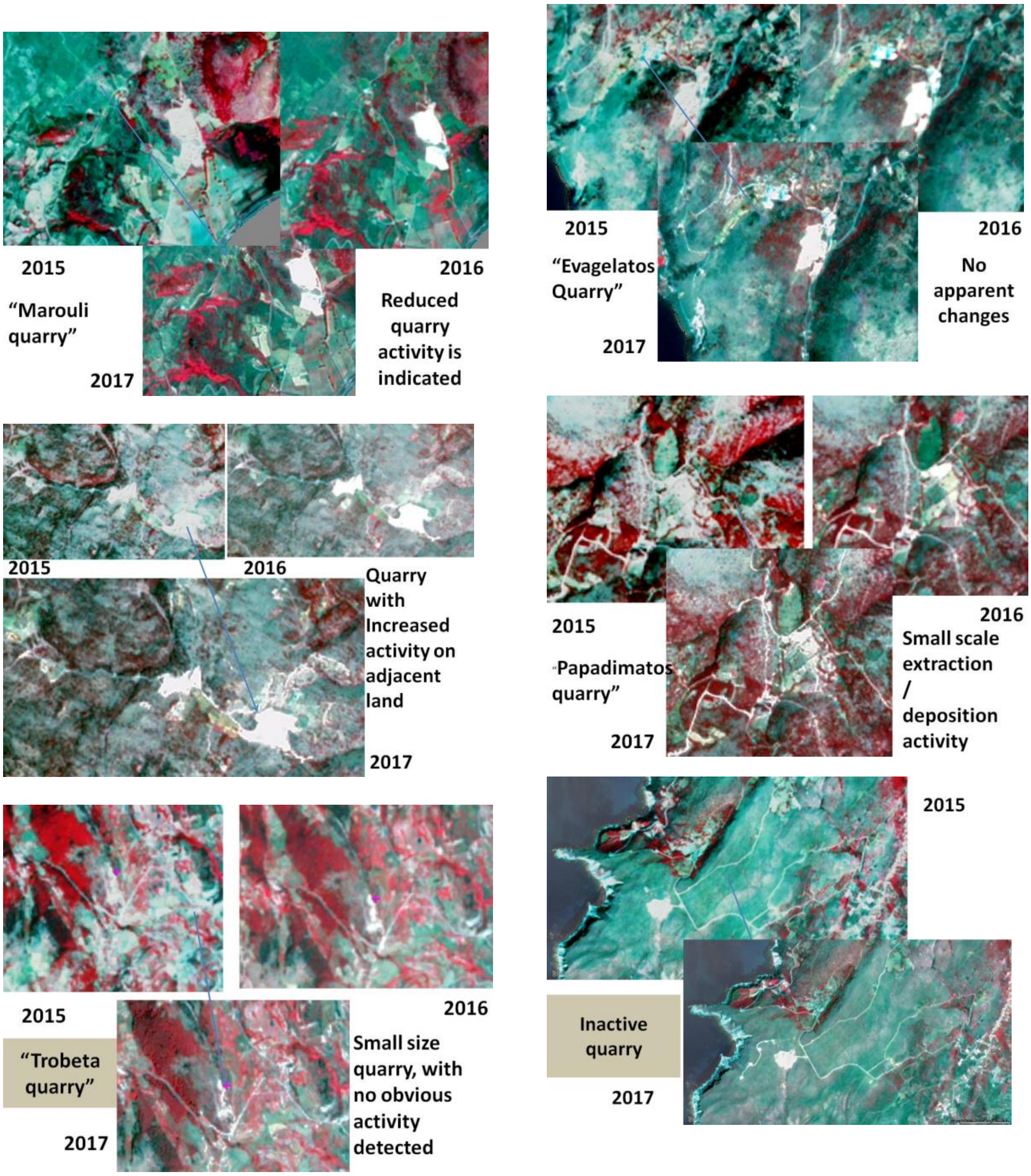


Fig. 5-2 Consultation with the End-User: Visual evaluation by the End User of enhanced multi-temporal, Sentinel 2 images in relation to quarry areas of Cephalonia Island.

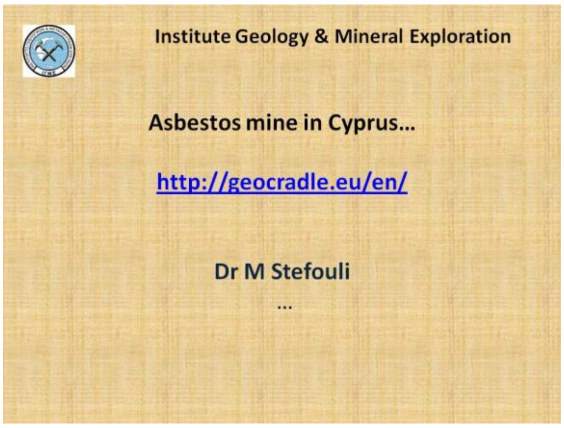
5.2. Cyprus

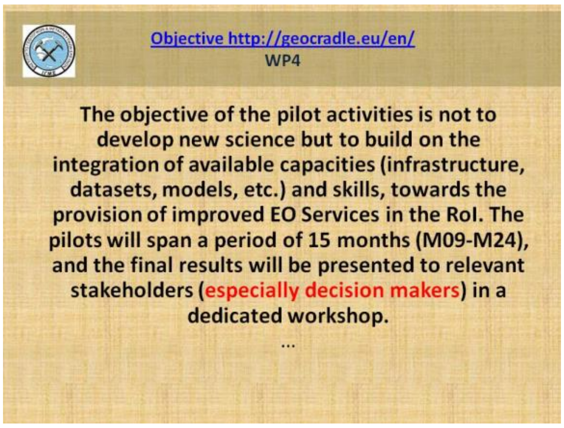
After the application of image processing techniques, consultation with the End User has taken place. Consultation included visual evaluation of processed Sentinel 2 time series data. The visual assessment of surface changes of the mining area by the End User has taken place. Results are shown on Fig. 5-3.

End User consultation also resulted in a need of making spatial information available to all staff members working in the mining area in an easily used form of an atlas-like manner. Computer users who have little training can then easily access and use the geospatial information. Main atlas capacities refer to establishment of objects and views so as to include all appropriate information of a stack of spatial information and display of multiple objects:
Side-by-side (before and after views),
Overlaying objects (vector and CAD lines of classification results over raster images / satellite images & ortho-photos on full spatial & temporal resolution),
Include graphical symbol overlays (such as icons or pie diagrams), or additional reference information (like map grids, text blocks, and legends),
Include object selection from spatially overlapping objects,
Easy navigation tools,
Simple-on-screen measurements,
Management of Hyper Index stacks of spatial information.

Atlas data and S/W can be installed on single-user machines or posted on a "network" but this is to be further clarified by the End User.

It is indicated that using the medium and high resolution satellite remote sensing data and integrated image processing and GIS techniques with parallel development of a geospatial database system provided monitoring and feedback at appropriate spatial scales for further use by the End User; The methodology can be used for long-term environmental management, and monitoring the mining area along with issues related to reclamation and rehabilitation.





Objective http://geocradle.eu/en/

PILOT 3 (T4.3): Access to Raw Materials (ARM)
Leader: EGS
For the first time, GEO-CRADLE will make available in the RoI the roadmap for long-term monitoring, mapping, and management of mineral deposits, also assessing the ground changes and site degradation relating to mineral exploitation. Diversified data sets together with their metadata will become accessible through the Regional Data Hub..
...

Objective http://geocradle.eu/en/

In the pilot project area of Abestos mine the following actions are taking place:

Monitoring the mining site and the restoration activities for the time interval of 2015 to 2017

Contribute to aspects of geologic and mining mapping of the area ...

Apply Earth Observation – EO techniques for engaging future operations fitted to monitoring the area so as to minimize the environmental footprint, and improve the evaluation of the sustainability and management of the post-mining areas...

EO data http://geocradle.eu/en/

In the current stage of analysis of the Asbestos mine the analysis and evaluation of Sentinel 2 EO data is taking place.

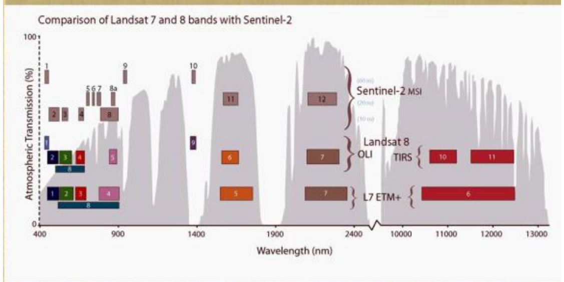
Why this EO system?

The Sentinel 2 satellite system has been financed and is part of the EU Copernicus Program

1. It is a relatively new system with the data acquisition started in the beginning of 2015.
2. Its specifications are comparable but with enhanced features in relation to other satellite systems like the Landsat series.
3. The data are freely available to the scientific community

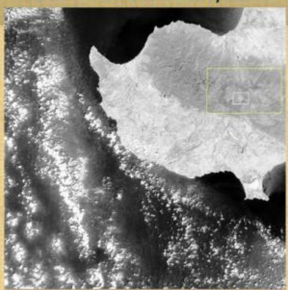
...

The SENTINEL 2 satellite system...



The Sentinel 2 systems covers 13 different spectral bands with a resolution ranging from 10 to 60 meters..

The SENTINEL 2 satellite system...

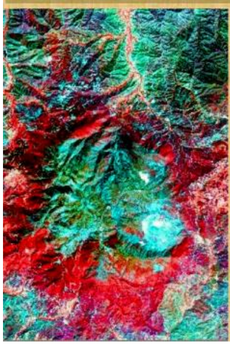


The size of the area coverage of each frame is ~12062 Km² The temporal resolution is ~ every week (When mission is to be accomplished with Sentinel 2C there will be an image available every three days... Exploitation depends on the cloud coverage!)

Asbestos mine - Cyprus...

Acquisition of Sentinel 2 images in three different dates i.e. 2015, 2016 & 2017 has taken place. The size of the Asbestos pilot project areas are: 1. A Regional area of 503.2 km² & a local area of 26.28 km²

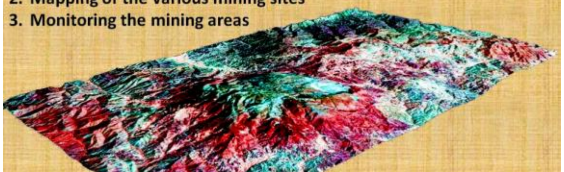
Asbestos mine - Cyprus...



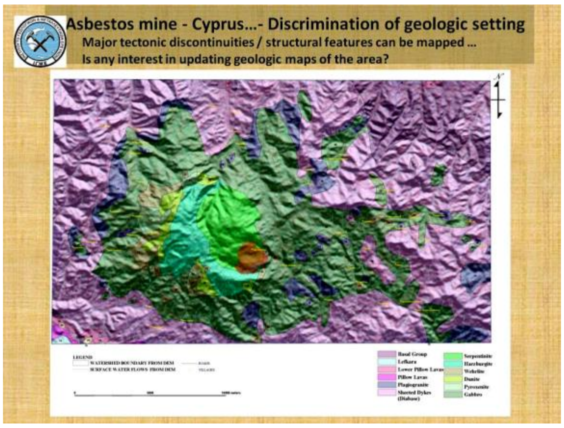
Multi-temporal Sentinel 2 data for the time interval of 2015 to 2017 have been collected for the area of interest.
Digital Elevation Models are used as an additional information data layer along with available land cover data, geologic / mining / environmental information when available...
A number of processing tasks like band ratios, principal component analysis, and data fusion techniques are applied for the enhancement of the Sentinel-2 images

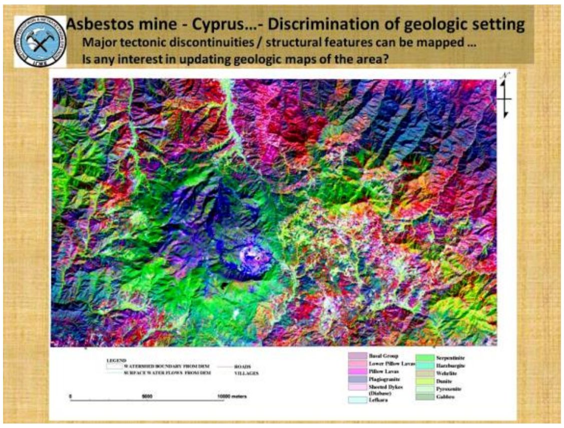
Asbestos mine - Cyprus...

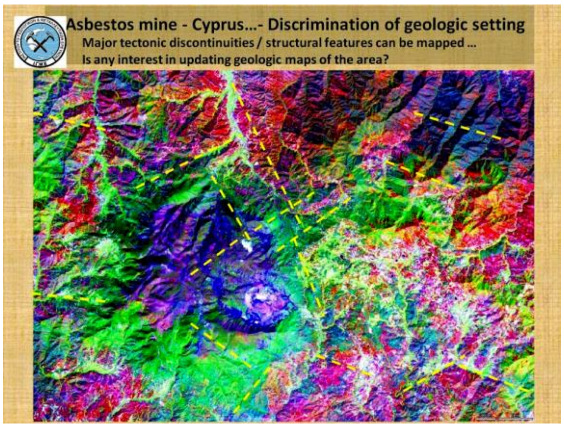
Different image products are evaluated in terms of
1. contribution to geologic mapping
2. Mapping of the various mining sites
3. Monitoring the mining areas

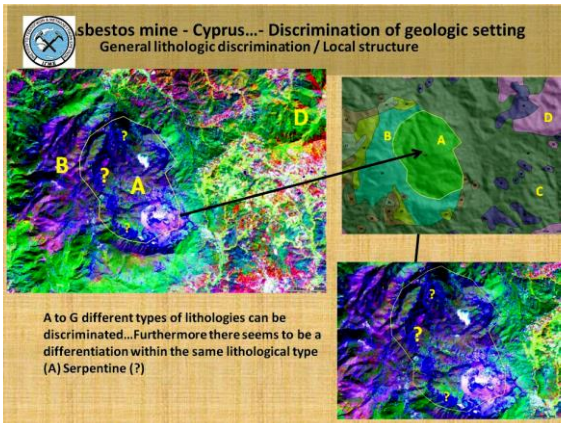


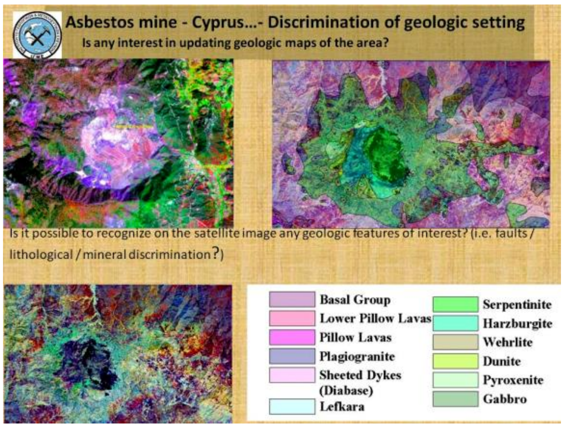
Enhanced images can be viewed as stereo using Anaglyph 3D Glasses

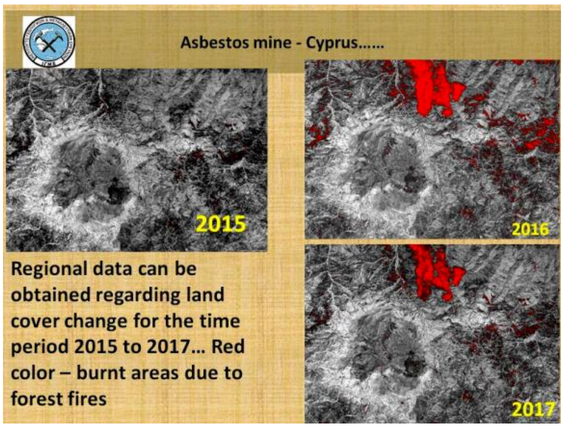

Asbestos mine - Cyprus...- Discrimination of geologic setting
Major tectonic discontinuities / structural features can be mapped ...
Is any interest in updating geologic maps of the area?

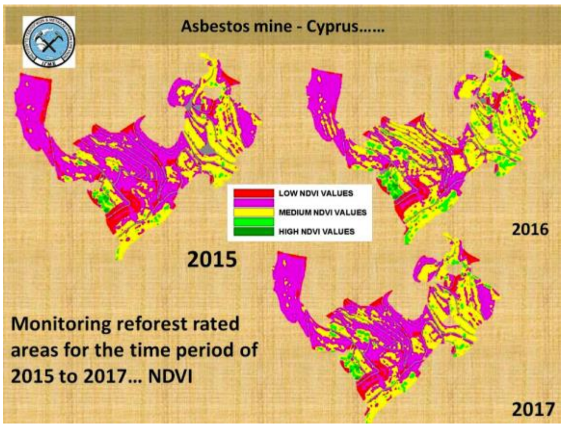

Asbestos mine - Cyprus...- Discrimination of geologic setting
Major tectonic discontinuities / structural features can be mapped ...
Is any interest in updating geologic maps of the area?

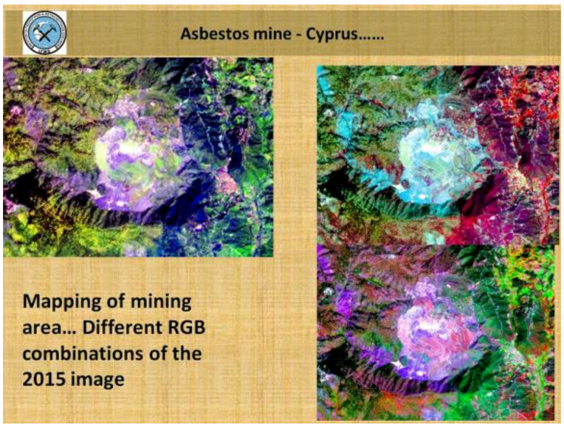

Asbestos mine - Cyprus...- Discrimination of geologic setting
Major tectonic discontinuities / structural features can be mapped ...
Is any interest in updating geologic maps of the area?


sbestos mine - Cyprus...- Discrimination of geologic setting
General lithologic discrimination / Local structure
A to G different types of lithologies can be discriminated...Furthermore there seems to be a differentiation within the same lithological type (A) Serpentine (?)


Asbestos mine - Cyprus...- Discrimination of geologic setting
Is any interest in updating geologic maps of the area?
Is it possible to recognize on the satellite image any geologic features of interest? (i.e. faults / lithological / mineral discrimination?)
Basal Group
Lower Pillow Lavas
Pillow Lavas
Plagiogranite
Sheeted Dykes (Diabase)
Lefkara
Serpentinite
Harzburgite
Wehrlite
Dunite
Pyroxenite
Gabbro


Asbestos mine - Cyprus......
2015
2016
2017
Regional data can be obtained regarding land cover change for the time period 2015 to 2017... Red color – burnt areas due to forest fires


Asbestos mine - Cyprus......
LOW NDVI VALUES
MEDIUM NDVI VALUES
HIGH NDVI VALUES
2015
2016
2017
Monitoring reforest rated areas for the time period of 2015 to 2017... NDVI


Asbestos mine - Cyprus......
Mapping of mining area... Different RGB combinations of the 2015 image

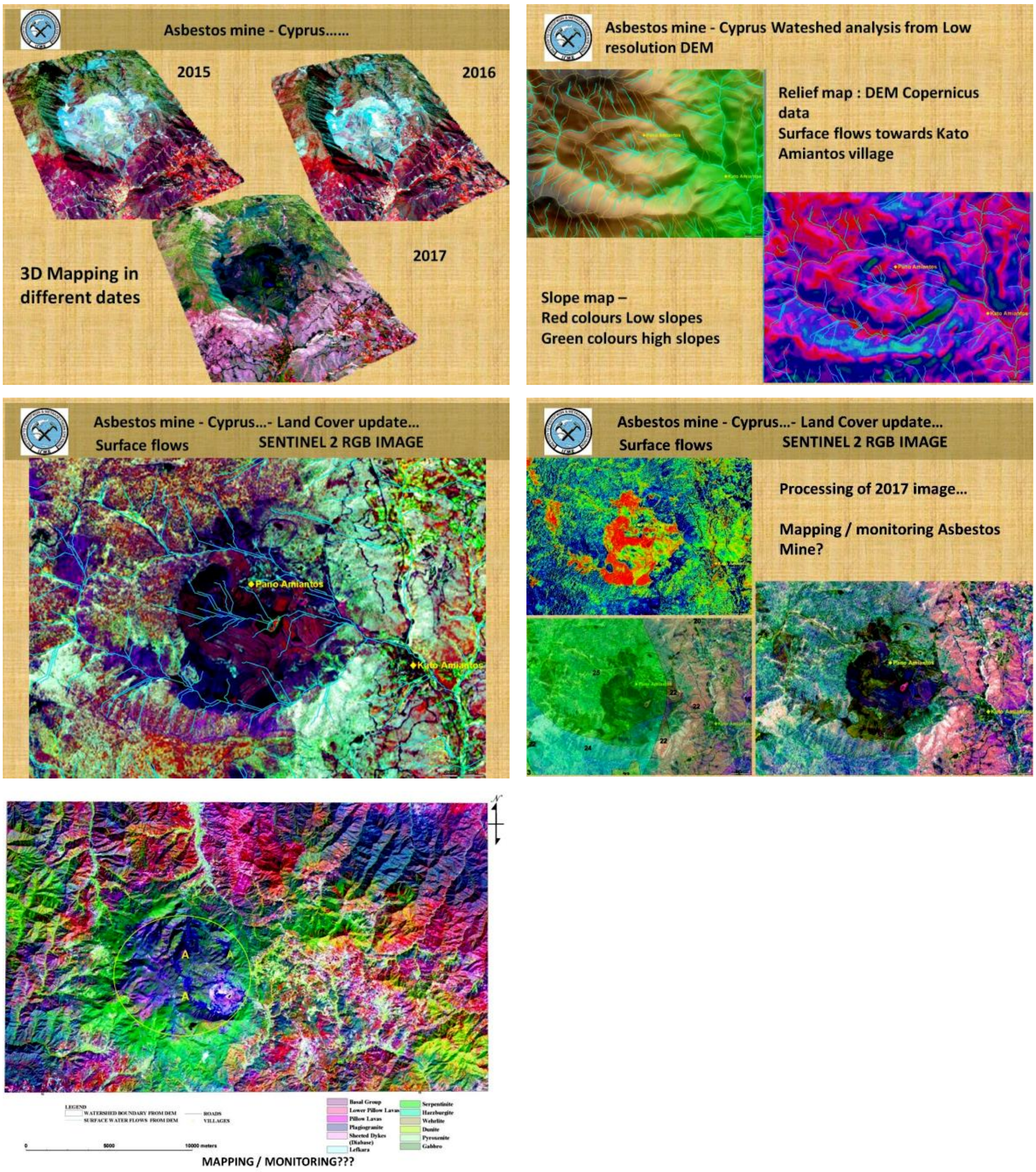


Fig. 5-3 Consultation with the End-User: Visual evaluation of processed images and identification of processing techniques to be applied.

5.3. Turkey I

After the application of image processing techniques, consultation with the End User has taken place. Intended consultation included visual evaluation of processed Sentinel-2 time series data. There is no particular response by the End User to it, Fig. 5-4. However there is a request for monitoring water surfaces and lithologies related to "tuffs".

Institute Geology & Mineral Exploration

Coal mining in Turkey

http://geocradle.eu/en/

Dr M Stefouli

...

Coal mining in Turkey
Objective http://geocradle.eu/en/

In the pilot project area of coal mining areas in Turkey the following actions are taking place:

Contribute to aspects of geologic and mining mapping of the area...
Monitoring the mining activity

An objective is to promote specifications and methodologies of Earth Observation – EO techniques for engaging future operations fitted to raw materials exploration and monitoring so as to minimize the environmental footprint, and improve the evaluation of the sustainability and management of the post-mining areas...

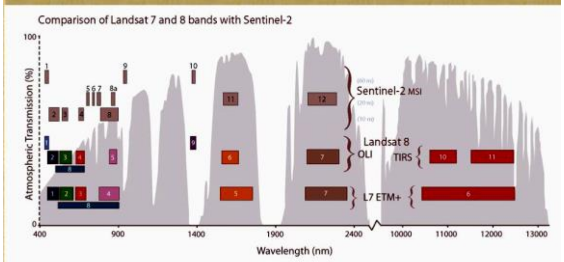
Coal mining in Turkey
EO data http://geocradle.eu/en/

In the current stage of analysis of the coal mining areas the analysis and evaluation of Sentinel 2 EO data is taking place.

Why this EO system?
The Sentinel 2 satellite system has been financed and is part of the EU Copernicus Program
1. It is a relatively new system with the data acquisition started in the beginning of 2015.
2. Its specifications are comparable but with enhanced features in relation to other satellite systems like the Landsat series.
3. The data are freely available to the scientific community

...

Coal mining in Turkey
The SENTINEL 2 satellite system...



The Sentinel 2 systems covers 13 different spectral bands with a resolution ranging from 10 to 60 meters. .

Coal mining in Turkey
The SENTINEL 2 satellite system...

The size of the study area is 15375 Km^2 and so a mosaic has been made using different frames of similar date i.e August 2017. Due to the size of the area there are some clouds in the North Eastern part of the image...

Coal mining in Turkey

Digital Elevation Models are used as an additional information data layer along with available land cover data, geologic / mining / environmental information when available...
A number of processing tasks like contrast stretching, principal component analysis, and data fusion techniques are applied for the enhancement of the Sentinel-2 image mosaic.

Coal mining in Turkey...

Different image products are evaluated in terms of
1. contribution to geologic mapping
2. Mapping of the various mining sites Corine land cover information concerning the mining areas has been extracted & over-layed on the image mosaic

Enhanced images can be viewed as stereo using Anaglyph 3D Glasses

The Kirikkale mining area - Turkey...

All mining areas of the area can be mapped and monitored – Location of mines follow NE trending tectonic lines – faulting (?)

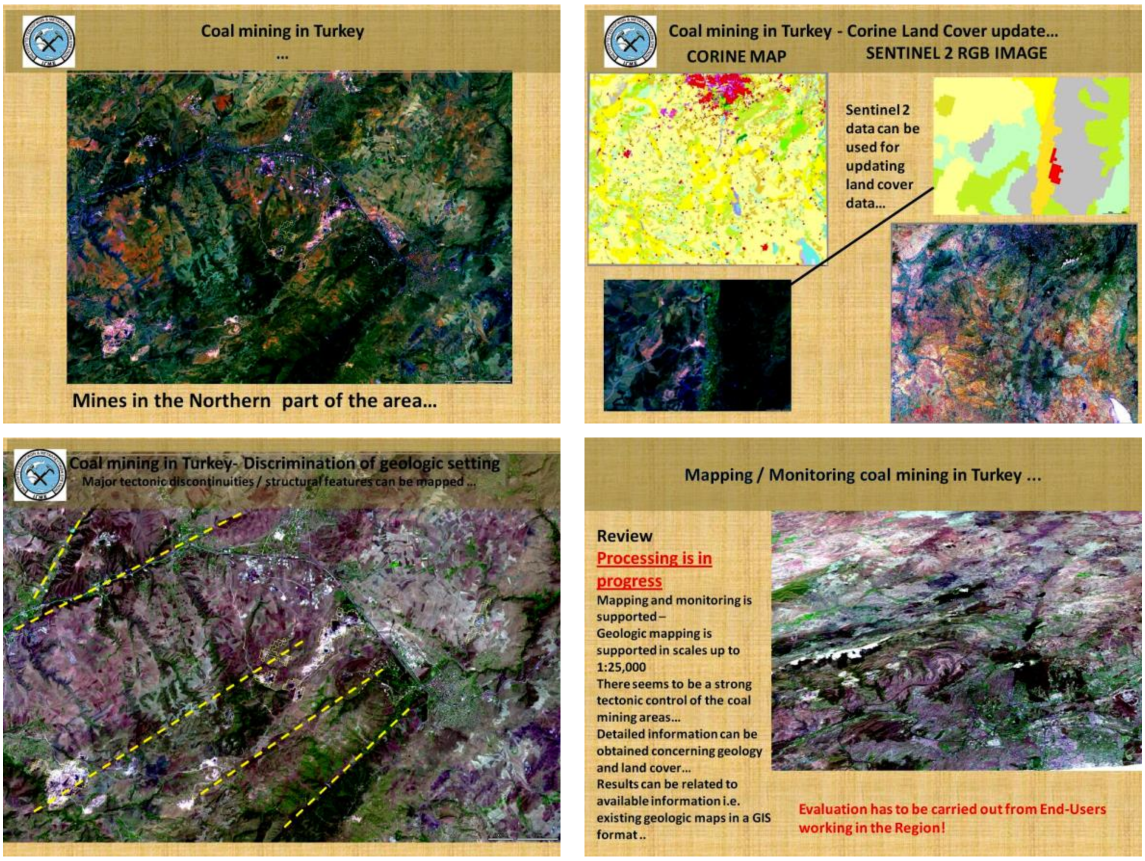
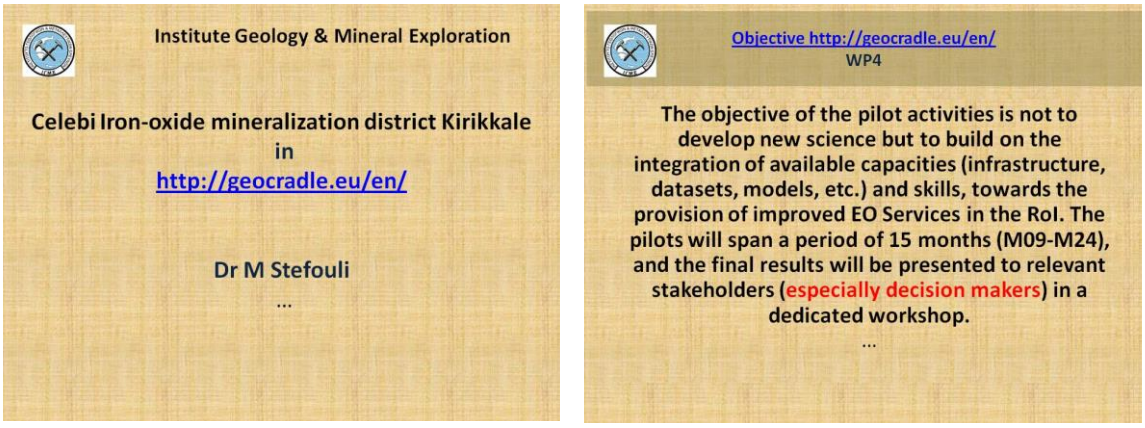


Fig. 5-4 Results of "consultation process".

5.4. Turkey II

After the application of image processing techniques, consultation with the End User has taken place. Consultation included visual evaluation of processed Sentinel-2 time series data. The visual assessment of surface changes of the mining area by the End User has taken place. Results are shown on Fig. 5-5.



Objective http://geocradle.eu/en/

PILOT 3 (T4.3): Access to Raw Materials (ARM)
Leader: EGS
For the first time, GEO-CRADLE will make available in the RoI the roadmap for long-term monitoring, mapping, and management of mineral deposits, also assessing the ground changes and site degradation relating to mineral exploitation. Diversified data sets together with their metadata will become accessible through the Regional Data Hub..
...

Objective http://geocradle.eu/en/

In the pilot project area of Celebi Iron-oxide mineralization district Kirikkale the following actions are taking place:

Monitoring the mining activity

Contribute to aspects of geologic and mining mapping of the area...

An objective is to promote specifications and methodologies of Earth Observation – EO techniques for engaging future operations fitted to raw materials exploration and monitoring so as to minimize the environmental footprint, and improve the evaluation of the sustainability and management of the post-mining areas...

EO data http://geocradle.eu/en/

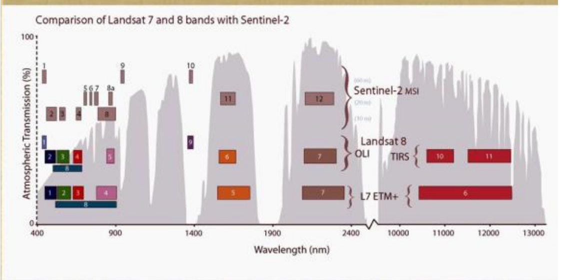
In the current stage of analysis of the Kirikkale mining area the analysis and evaluation of Sentinel 2 EO data is taking place.

Why this EO system?
The Sentinel 2 satellite system has been financed and is part of the EU Copernicus Program

1. It is a relatively new system with the data acquisition started in the beginning of 2015.
2. Its specifications are comparable but with enhanced features in relation to other satellite systems like the Landsat series.
3. The data are freely available to the scientific community

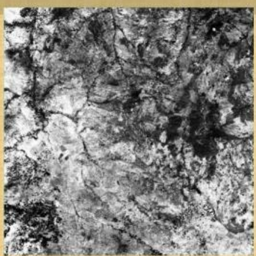
...

The SENTINEL 2 satellite system...



The Sentinel 2 systems covers 13 different spectral bands with a resolution ranging from 10 to 60 meters..

The SENTINEL 2 satellite system...

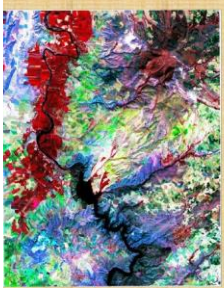


The size of the area coverage of each frame is ~12062 Km² The temporal resolution is ~ every week (When mission is to be accomplished with Sentinel 2C there will be an image available every three days... Exploitation depends on the cloud coverage!)

The Kirikkale mining area - Turkey...

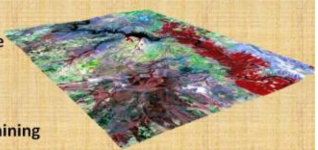
Acquisition of Sentinel 2 images in two different dates i.e. 2015 & 2017 has taken place. The size of the Kirikalle mining pilot project area is 327.7 km2

The Kirikkale mining area - Turkey......



Multi-temporal Sentinel 2 data for the time interval of 2015 to 2017 have been collected for the area of interest.
Digital Elevation Models are used as an additional information data layer along with available land cover data, geologic / mining / environmental information when available...
A number of processing tasks like band ratios, principal component analysis, and data fusion techniques are applied for the enhancement of the Sentinel-2 images

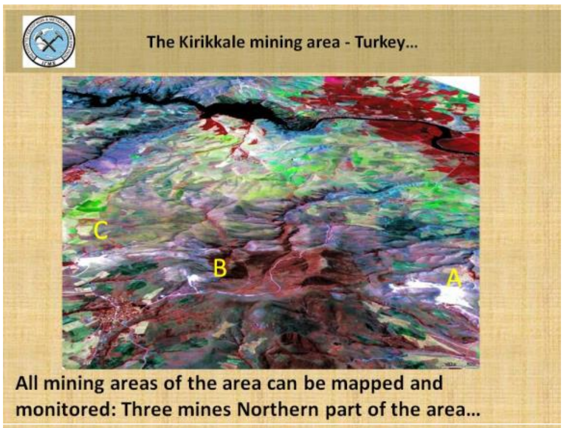
The Kirikkale mining area - Turkey...

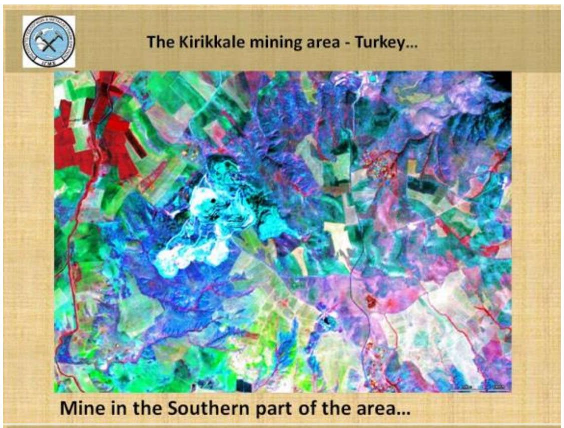


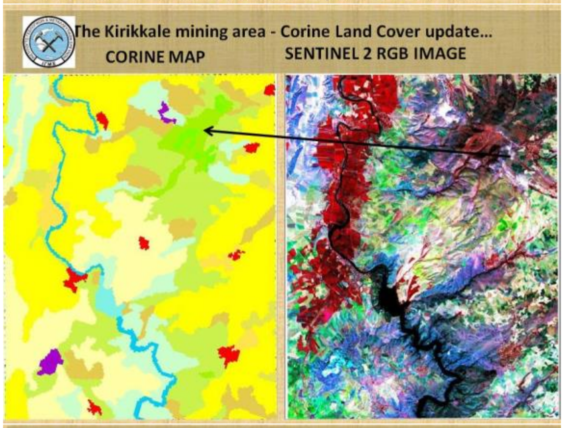
Different image products are evaluated in terms of

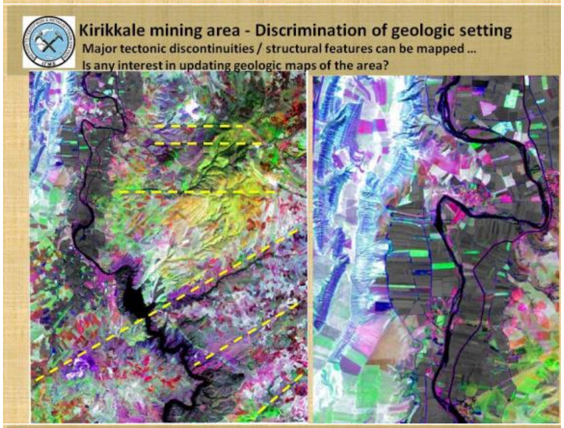
1. contribution to geologic mapping
2. Mapping of the various mining sites
3. Monitoring the mining areas

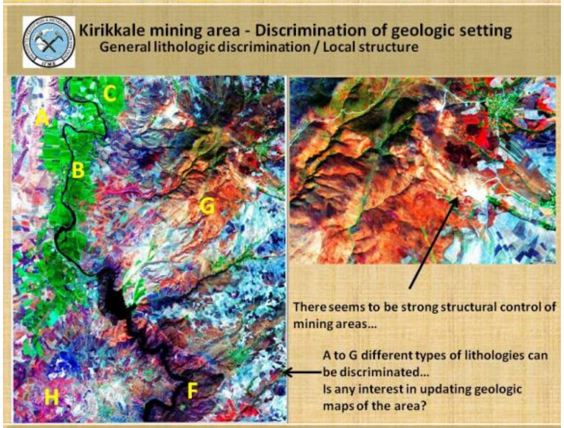
Enhanced images can be viewed as stereo using Anaglyph 3D Glasses

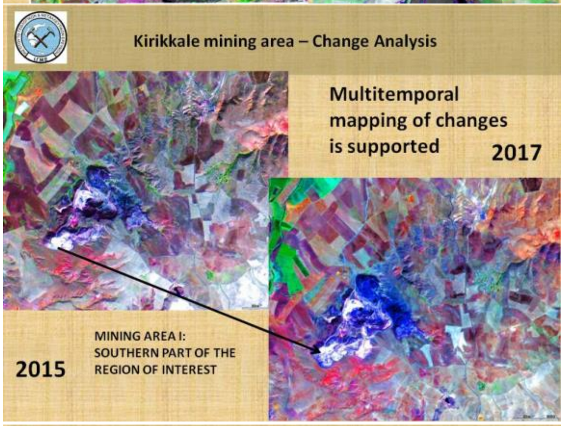

The Kirikkale mining area - Turkey...
C
B
A
All mining areas of the area can be mapped and monitored: Three mines Northern part of the area...

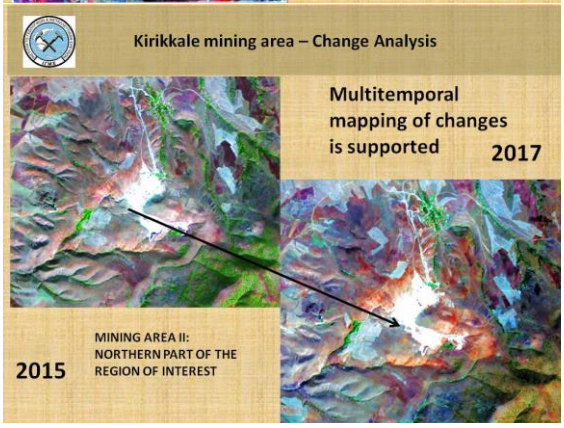

The Kirikkale mining area - Turkey...
Mine in the Southern part of the area...

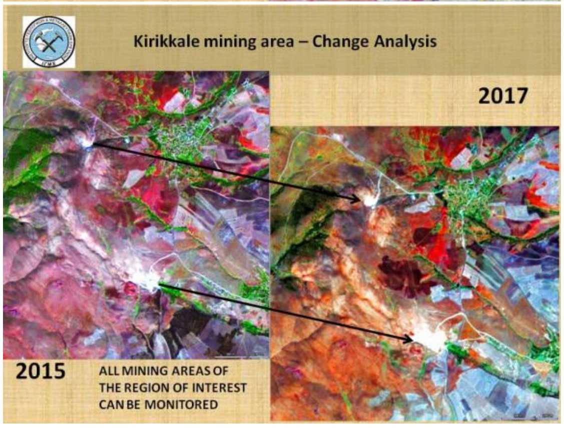

The Kirikkale mining area - Corine Land Cover update...
CORINE MAP
SENTINEL 2 RGB IMAGE

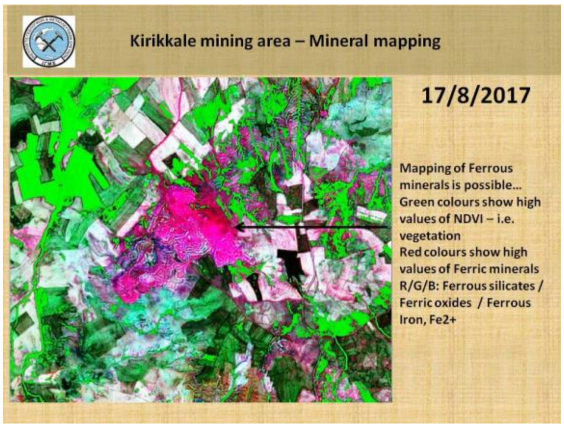

Kirikkale mining area - Discrimination of geologic setting
Major tectonic discontinuities / structural features can be mapped ...
Is any interest in updating geologic maps of the area?


Kirikkale mining area - Discrimination of geologic setting
General lithologic discrimination / Local structure
C
A
B
G
H
F
There seems to be strong structural control of mining areas...
A to G different types of lithologies can be discriminated...
Is any interest in updating geologic maps of the area?


Kirikkale mining area – Change Analysis
Multitemporal mapping of changes is supported
2017
2015
MINING AREA I: SOUTHERN PART OF THE REGION OF INTEREST


Kirikkale mining area – Change Analysis
Multitemporal mapping of changes is supported
2017
2015
MINING AREA II: NORTHERN PART OF THE REGION OF INTEREST


Kirikkale mining area – Change Analysis
2017
2015
ALL MINING AREAS OF THE REGION OF INTEREST CAN BE MONITORED



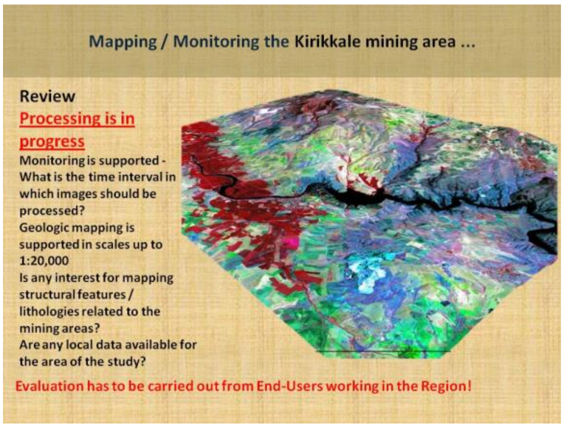


Fig. 5-5 Results of "consultation process".

6. Dissemination and implementation of the pilot results

6.1. Pilot results in the European Geological Data Infrastructure

European Geological Data Infrastructure (EGDI) is EuroGeoSurveys' web-portal:

http://www.europe-geology.eu/

It provides access to Pan-European and national geological datasets and services from the Geological Survey Organizations of Europe. The users can choose one of the main geological topics from the menu: Onshore, Marine, Minerals, Geohazards, Energy, Soil and Groundwater. The portal provides also the view of the data through the map-viewer, where available datasets can be displayed as layer on the topographic map of Europe. Experienced users can access compiled maps and data directly by choosing from the submenus. Searching the site is supported using the search bar or the MICKA metadata catalogue.

Access to Raw Materials pilot results are available thought EGDI portal. The data are placed in "Mineral Resources" sector, under "GEOCRADLE" group of layers (Fig. 6-1).

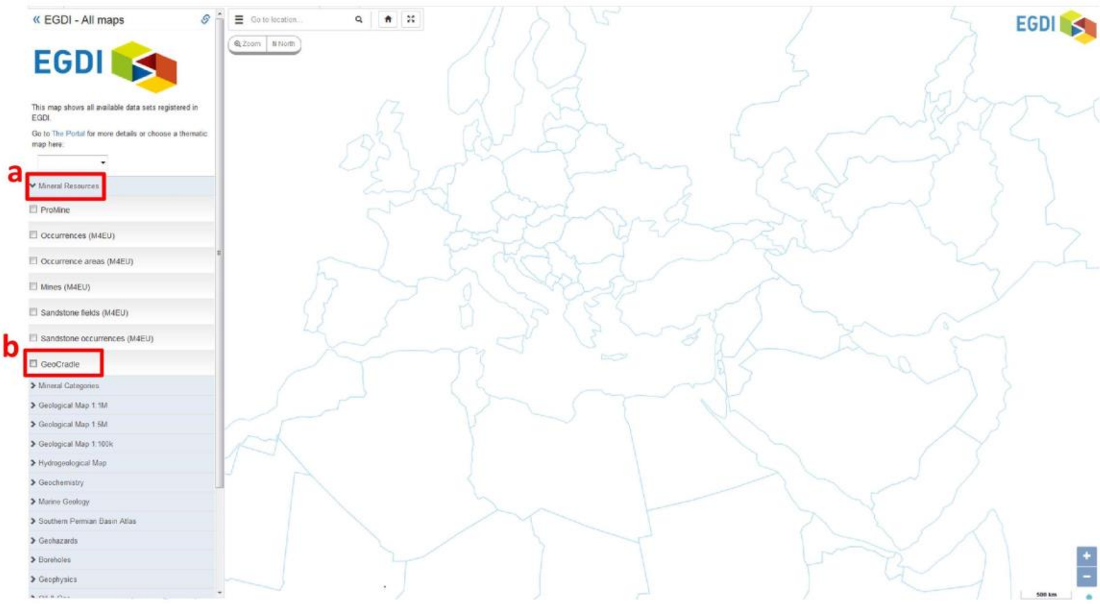


Fig. 6-1 Map viewer in EGDI portal (http://www.europe-geology.eu/map-viewer/). Note the parts indicated in red blocks: a. Thematic group of the data "Mineral Resources", b. GEO-CRADLE Access to Raw Materials layers among Mineral Resources group.

The datasets include 63 raster files, which are grouped depending on the pilot test site: Cyprus Asbestos Mine, Turkey Celebi-Kesikopru District, Turkey Central Anatolian, Greece - Quarries in Attica Region and Greece - Quarries in Cephalonia. For each of these regions, layers present the results of the different processing methods or additional data used for the mining or post-mining area (Fig. 6-2).

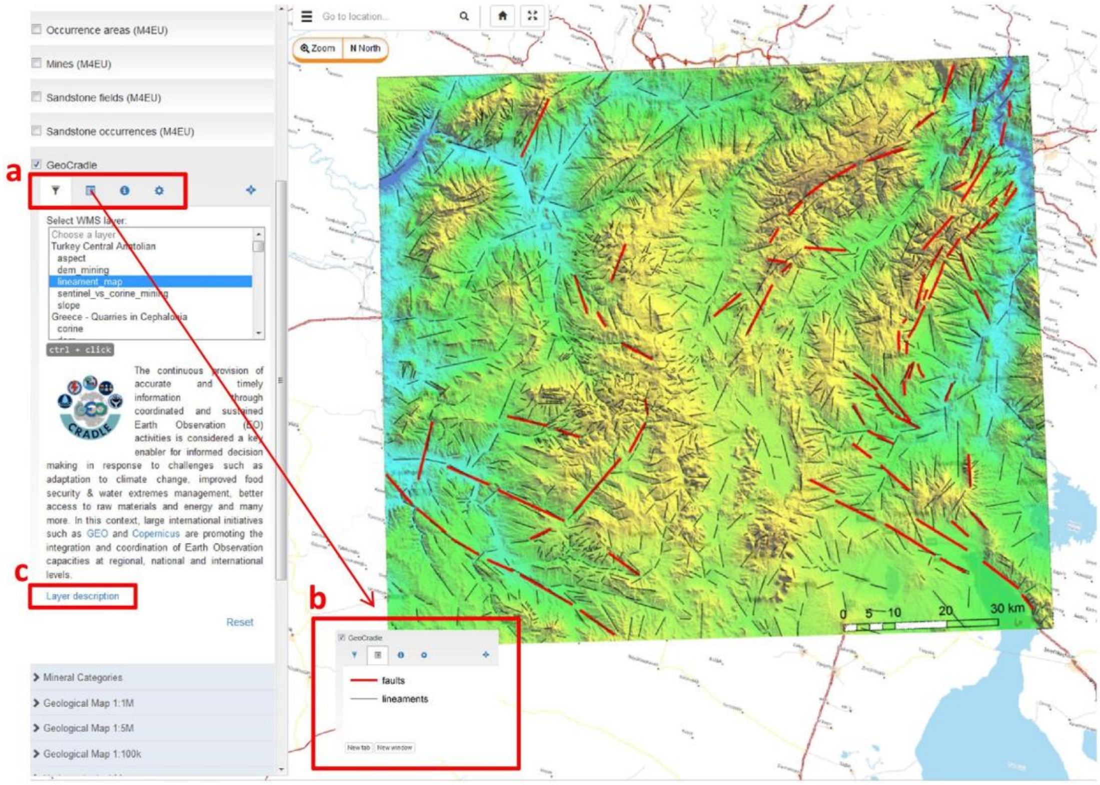


Fig. 6-2 Map viewer in EGDI portal (http://www.europe-geology.eu/map-viewer/), example of the GEO-CRADLE ARM pilot layer. Note the parts indicated in red blocks: a. After selecting the layer, the following tabs are available: Filter of the layers, Legend of the chosen layer, Description (metadata) and Set up. b. Legend tab, c. Layer description tab in the bottom of the Filter allows opening the new window with the text description of the data.

6.2. Pilot results in GEO-CRADLE Regional Data Hub

Access to Raw Materials pilot results are also available through the GEO-CRADLE Regional Data Hub (GCRDH):

http://datahub.geocradle.eu/

In the "Pilot 3" group, users can find a list of all products (Fig. 6-3). The products are described and available for download.

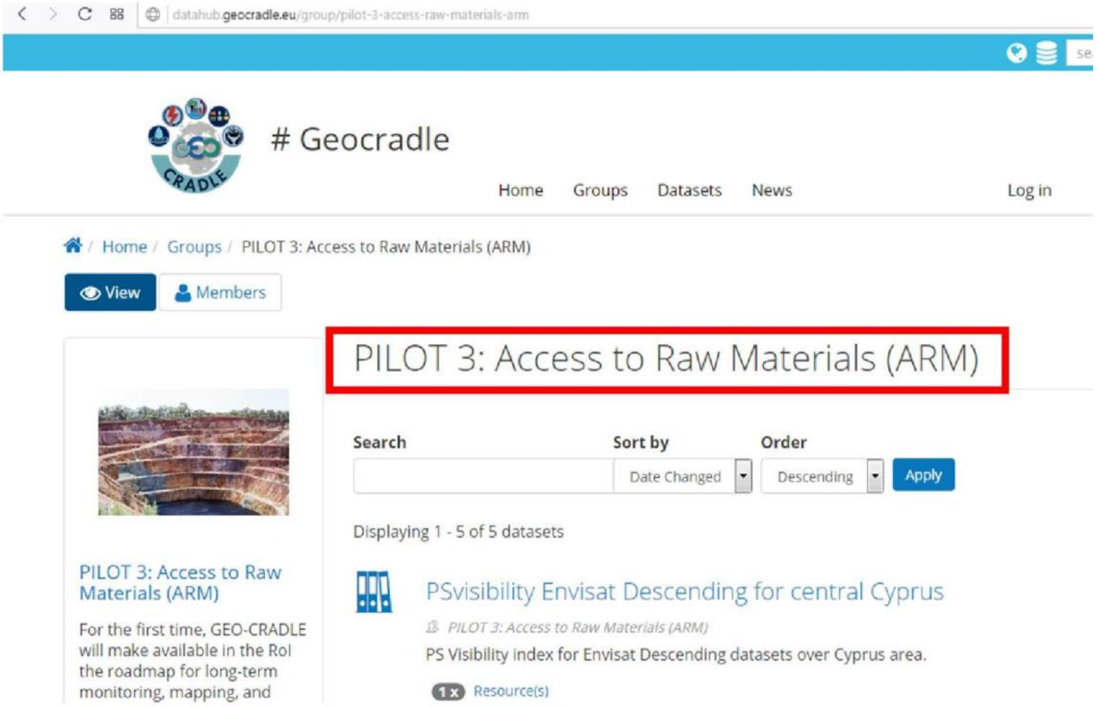


Fig. 6-3 GEO-CRADLE Regional Data Hub (GCRDH): http://datahub.geocradle.eu/. Access to Raw Materials pilot results are available under "Pilot 3" group.

All the layers are the same like in EGDI portal (chapter 6.1), however they are grouped not only by the geographic location, but also by the processing method. Therefore under one "dataset" in GCRDH, the user can find few "resources", meaning few layers (Fig. 6-4).

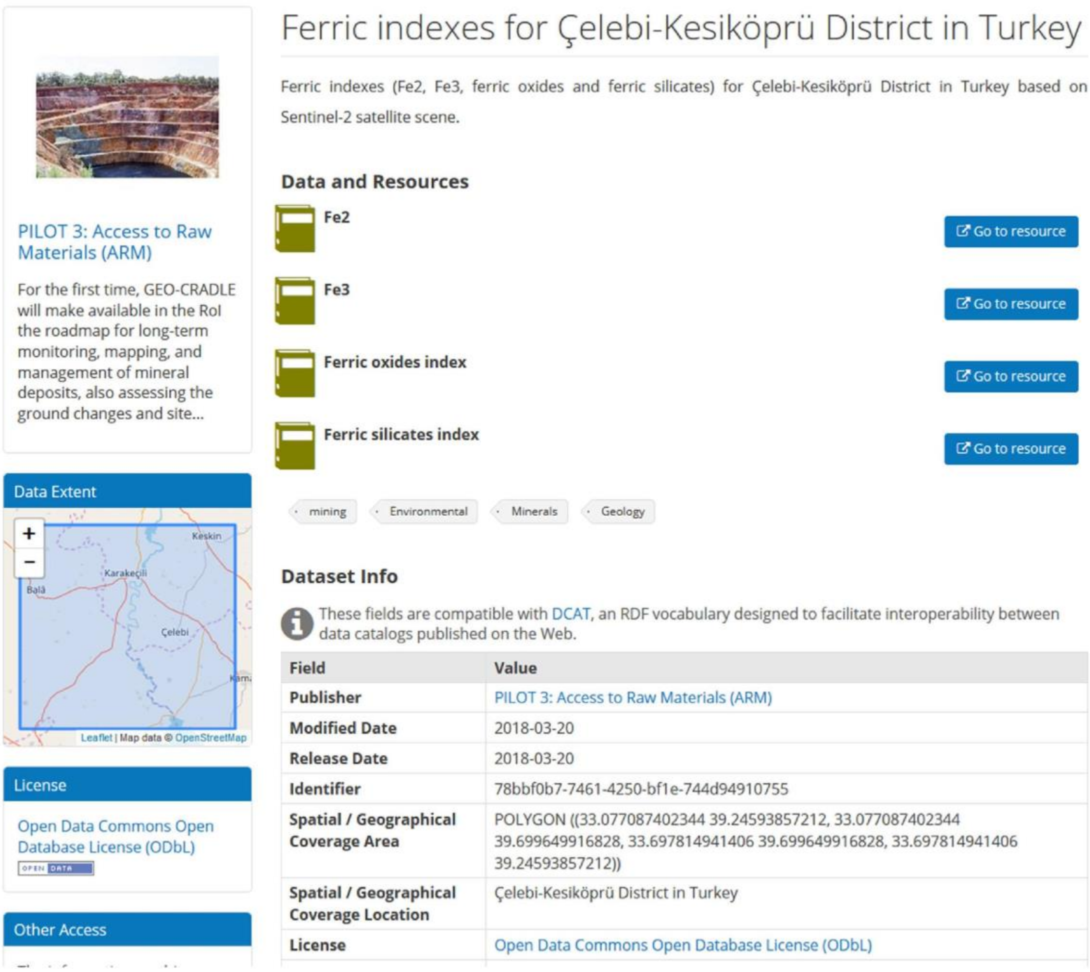


Fig. 6-4 GEO-CRADLE Regional Data Hub (GCRDH): http://datahub.geocradle.eu/. Example of the ARM dataset, which contains four layers of the iron-indexes analysis over Celebi-Kesikopru district in Turkey.

6.3. Dissemination activities

During the project, GEO-CRADLE with a special focus on "Access to Raw Materials" pilot was presented, promoted and disseminated on the following events:

1. "Copernicus for Raw Materials Workshop", 5th September, 2016, Brussels. Gerardo Herrera in his presentation "Earth Observation for Raw Materials from EuroGeoSurveys", presented GEO-CRADLE as one of the projects that EGS is contributing to build a community of remote sensing users and service developers in the industry of raw materials and extractive industries. The workshop audience was composed of users, service providers and representatives from the scientific community, EC DGs, several Copernicus Committee & Copernicus User Forum delegates, international organisations and space agencies, around 90 people attended.

2. EGS General Meeting, 11th of October 2016 in Ljubljana, Slovenia, hosted by the Geological Survey of Slovenia. Isabel Pino made an update of the GEO-CRADLE project to the EGS Directors. A total of 35 EGS members coming from 34 countries attended the General Meeting. Most of the EGS members from the Balkans region participated the event (The Geological Survey of Bosnia & Herzegovina, The Geological Survey Croatia, The Geological Survey of Serbia, The geological Survey of Cyprus, The Geological Survey of FYROM, The Geological Survey of Greece, the Albanian Geological Survey and The Geological Survey of Kosovo).

3. "Addressing GEO-CRADLE regional challenges - Access to raw materials" - 2nd EGS Networking event "Aimed at in-situ network operators and Geological Surveys – especially in Middle East and North Africa (MENA)", 17th October 2016, Rabat, Morocco. The meeting was attended by over 40 participants representing the GeoScience Community in Morocco including universities and government institutions at high level, 10 Geological Surveys and GEO-CRADLE partners (including project coordinator). The meeting was co-organized by the Geological Survey of Morocco and EuroGeoSurveys and was hosted by the Minister of Energy, Mining, Water and Environment of the Kingdom of Morocco.

4. 2nd EGS Networking event "Aimed at in-situ network operators and Geological Surveys – especially in Middle East and North Africa (MENA)", 19-23 October 2016, Timimoun, Algeria. The event was organised in the framework of the Algerian 5th National Stratigraphy Workshop, which was attended by over 200 participants representing the whole Algerian geoscientific community, mainly from universities and governmental institutions at the highest levels. The heads and managers of all the main Algerian state-enterprises attended the meeting in Timimoun. Also Tunisia was represented at Director General level. The GEO-CRADLE partners presented several aspects of the project via different presentations in plenary session, raising a big deal of attention. The EGS Secretary General made an introduction to the broad scope of the project, explaining the role of Geological Surveys and of the raw materials topics in the framework of GEOSS and COPERNICUS.

5. During the GEO-CRADLE Project Meeting "Refining the scope of the pilots towards regional challenges (WP4) in light of WP3 outcomes", 17th November 2016, Limassol, Cyprus, EGS took the opportunity to disseminate the project to the Geological Survey of Cyprus which one has provided some pilot test sites and have shown a real commitment with the project. The EGS Delegation had also the opportunity to meet the private sector in the island and explore future collaboration (visit to the Skouriotissa Copper mine).

6. EGS Executive Committee, 12nd December 2016. The event was EGS internal meeting of Executive Committee during which Isabel Pino made an update to the EGS networking event organized in Morocco and Algeria.

7. 20th January 2017, St. Petrersburg, 135th Anniversary VSEGEI (Geological Survey of Russia). Presentation done by Luca Demicheli on EuroGeoSurveys general activities and projects (among which GEO-CRADLE).

8. 15-17th February 2017, Paris, International Union of Geological Sciences (IUGS) Meeting. Presentation done by Luca Demicheli- General EGS presentation and its projects.

9. 3-10th February 2017, Cape Town, south Africa, Event: MINING INDABA. Presentation done by Celine Andrien and Claudia Delfini - general presentation of EGS and its project at the EGS booth (screen with a presentations in a loop mode).

10. 13th February 2017, Brussels, EGS National Delegates and EGS Chairs of the Expert Groups. Presentation done by Gerardo Herrera on Earth Observation and Geohazard Expert Group annual activities and future plans (within which GEO-CRADLE is one of the projects). The meeting was attended by EGS National delegates, EGS Chairs of the Expert Groups and EGS Secretariat.

11. 28-29th March 2017, Brussels, EGS General Meeting and Directors' workshop. Presentation done by Isabel Pino: Debrief on the main Expert Groups and Task Forces activities over the previous six months; • debrief on the status of concluded or on-going projects, as well as on submitted proposals: ProSUM; GEO-CRADLE; MICA; MINLAND; INTERMIN. • inform on upcoming changes in the EGS Expert Groups leadership. The meeting was attended by 35 Geological Surveys Directors and the EGS Secretariat.

12. EGS Secretariat collected at the begging of the 2017 year the annual reports from the Expert Groups (a detail summary of their activities and projects) and then together with other information prepared the EGS Annual Report. The Annual report was distributed to our community (European Geological Surveys) and also our stakeholders. It was also published in the EGS website. The Annual Report 2016 included the GEO-CRADLE as a new project that kicked off at the begging on 2016.

13. April 2017, EGS has attended the European Geosciences Union General Assembly (EGU) 2017 in Vienna, Austria. The assembly is a genuine opportunity to discuss and share ideas with experts in all fields of geoscience. It brings together scientists from all over the world, gathering up to 107 different countries. During the EGU 2017 assembly, GEO-CRADLE has been promoted through promotional materials such as brochures and bookmarks displayed on our stand and spread during

networking events. Moreover a TV screen was displaying the EGS activities and the GEO-CRADLE platform has been mentioned. Regarding the social media activities, a tweet from our EGS twitter account has also been published to promote the platform.

14. On 29th of May 2017 Geo-Cradle project was presented during the Earth Observation and Geohazards Expert Group of EuroGeoSruveys. The meeting was attended by 23 people, representing 15 European Geological Surveys, including Balkan countries. The presentation gave the update of the project activities, especially in the Access to Raw Material thematic area.

15. EGS twitter channel: https://twitter.com/EuroGeoSurveys/status/856454008776650753

16. On the 5th of September 2017 Isabel Pino made a general presentation on GEO-CRADLE to the EGS National Delegates Forum in Vienna hosted by the Geological Survey of Austria (GSA). The audience was around 30 people from 25 countries.

17. 9-17 September 2017 during the 82nd Thessaloniki International Fair (http://tif.helexpo.gr/en/) Kiki Hatzilazaridou promoted the Access to Raw Materials pilot in a booth with brochures and video-presentation. The audience included 30 people (including students, researchers, general public).

18. On 11 October 2017 Eleftheria Poyiadji gave presentation in Belgrade-Serbia during the EuroGeoSurveys Directors' Workshop - "RS Mineral Resources Potential". The audience included the directors and scientists from Geological Surveys of Europe.

19. On 23-27 October 2017, in Washington D.C., USA was held GEO-XIV Plenary Week. EGS delegation was present and ARM pilot was disseminated along with other Geo-Cradle activities in a booth with brochures, set up within the meetings.

20. On the 6th of November 2017 Isabel Pino made a presentation on GEO-CRADLE with focus on the ARM Pilot to the EGS Mineral Resources Expert Group. The audience was around 25 people. It took place in the Geological Survey of Belgium back to back with the Raw Materials week.

21. On 13th November Maria Przyłucka gave presentation on "Access to Raw Materials pilot activities and results" for Earth Observation and Geohazard Expert Group of EuroGeoSurveys during their annual meeting. The audience included 30 people form European geological surveys, experts in the field of Earth Observation as well as 6 other expert group chairs.

22. Dissemination of Access to Raw Materials pilot results via exchange of e-mails with the end-users after the preparation of power point presentations has also taken

place for the other 3 pilot project areas i.e. two in Turkey and one in Cyprus during November 2017.

23. On 19th July and 7th December 2017 two consultations with the End-User in Greece (dissemination of information) has taken place. Dissemination included the preparation of power point presentations and discussions on the premises of the Ministry. However there was also exchange of information through e-mails mainly during the period of the second half of 2017. The meetings were attended by Ministry of Environment and Energy and in particular the Special Secretariat of Inspectors – Auditors, Body of Inspection for Southern Greece, Department of Mining Inspection which is referred as End User in the report.

24. On EuroGeoSurveys National Delegates meeting, 26-27 February 2018 in Brussels, Gerardo Herrera, chair of the Earth Observation and Geohazards Expert Group presented GEO-CRADLE among other activities take by the group in 2017.

25. During “Sixth International Conference on Remote Sensing and Geoinformation of Environment” (RSCY2018) - Cyprus - March 26-29, 2018, Eleftheria Poyiadji gave a presentation titled: “Introduction of Remote Sensing Methods for Monitoring the Under Restoration Amiantos Mine, Cyprus”, disseminating the pilot results, focusing on Cyprus test site.

26. EGS had a booth at the EGU conference in Vienna, 8-13 April 2018 (https://www.egu2018.eu/ European Geosciences Union General Assembly 2018), where brochures and presentations on GEO-CRADLE were displayed.

27. On 12-13 April 2018 in Vienna, Austria, Earth Observation and Geohazard Expert Group of EuroGeoSurvey celebrated its annual meeting. Eleftheria Poyiadji presented ARM pilot results to the delegates from European Geological Surveys.

28. 7th Digital Earth Summit (DES-2018), 17-19th April, 2018, Morocco, Rabat. http://www.desummit2018.org/ (presentation under the tile: “Optimization of Sentinel 2 Data for Supporting Geological Mapping and Monitoring of Mining Areas” was given by Marianthi Stefouli from IGME-GR).

29. GEO meeting in Rome on 2nd-4th May 2018.

7. Sustainability

There is a high probability for sustainable realization and implementation of the pilot study:

- There are no legal regulations and obstacles, that may determine whether and to what extent the expected impacts will be achieved.
- Strategy for sustainability of the proposed activities and methodology was checked and confirmed during realization of other projects. It follows also international standards used in EU.
- The local administration is deeply interested and involved in environmental restoration of the former mining area, which could be of a high interest for development of touristic activities.
- The only risk related to proper realization of the pilot study is connected with poor quality of newly acquired satellite data. However, such risk is very small.
- Data from the Sentinel-1 and Sentinel-2 satellites are available for free and as such will be made available by the European Space Agency in the future as well. This will ensure that the proposed analysis can be carried out over the next years.
- Archival data, including radar data (ERS, Envisat) and optical (Landsat) data, are available free of charge. They are slightly worse resolution, but still they can be used for the analysis of the past. Such analyzes may be useful for assessing the effectiveness of rehabilitation works and their effects (e.g. assessing how quickly the environment in the area is changing compared to the intended plan).
- The use of remote sensing data in the area of abandon mine has a great potential. Rehabilitation works ongoing for years can be successfully supported by satellite imagery analysis. If it is planned to re-opened houses and optimum development of the area, monitoring using remote sensing methods can help in effective and secure spatial planning.
- The use of remote sensing data in the mining and post-mining areas can be implemented by the industry companies in the future. Scientific projects aimed at the use of these methods to study the potential of deposits and mineral mapping should include an element of cooperation with the mines and institutions representing the market.

Quality, safety and environmental protection, constitute significant challenges but also the most pressing needs of this era – deeply influencing not only the development of the mining industry, but also its traditional character of many centuries and finally its very existence. In this framework, the issues of acceptance from local populations, corporate social responsibility, systems of quality control, and systems that allow collection and disclosure of full and accurate information (Databases, GIS, etc.) are all of particular importance. Earth Observation data can contribute through supporting mapping and monitoring of quarry areas and also to the update of the GIS databases as they provide up to date data.

The activities undertaken at regional level by EGS (IGME – Greece) are focusing in the development of GEO-CRADLE tools appropriate to support the monitoring of legal and illegal quarrying activities by the competent authorities. A concise informative report is to be communicated to the End User.

The successful implementation of the pilot project reveals the need to disseminate information related to the usefulness of EO techniques in application related to mapping and monitoring of quarry areas, following different actions:

The outcomes of the pilot to be shared with all potential stakeholders with a public demonstration of the project results. A public demonstration of the project outcomes concerning the pilot cases is a potential imitative that EGS needs to undertake as a follow up activity. A leaflet is a potential alternative for broad dissemination of the results.

An additional initiative is to communicate the results to the Greek Mining Association in order to motivate the mining companies-members into considering or/and incorporating similar tools in their activities.

Also dissemination activities include our participation to the http://www.desummit2018.org/ - 7th Digital Earth Summit (DES-2018) conference which is taking place in Morocco, or the Sixth International Conference on Remote Sensing and Geo-information of Environment (RSCY2018) - CYPRUS - March 26-29, 2018 as they are both on the RoI countries.

Maintenance of a network capitalizing the GEO-CRADLE results needs to be undertaken.

Continuous work has to be undertaken in order to upgrade and further improve the methodologies involving EO techniques for the monitoring of legal or illegal quarrying, environmental monitoring and mining management support, e.g. with cost minimization, elimination of errors, increase the overall efficiency of processing techniques etc.

The Ministry of Environment and Energy has been under re-structuring and a new business plan has been established. End User needs may be differentiated and therefore, questions set in this paragraph cannot been fully answered at this time. This information may be available during the final delivery of this report.

8. Institutional and organizational capacity assessment of the implementation body

In order to perform earth observation analysis proposed to the study areas, special equipment and qualified staff is essential. Especially it is advised to:

- Have at least two employees with experience in satellite data processing, both radar and multispectral.
- The minimum hardware requirements are: 4 GB of RAM, a CPU with at least 2 cores and SSE2 support, OpenCL 1.2-compatible runtime with 1 GB of memory and FP64 support. However for large data sets such as radar data processed in interferometry technology, it is advisable to have better equipment, such as a graphics station with 32 GB of RAM and 2 processor of 2.30 GHz.
- For analysis, it is necessary to have the appropriate software. Free software can be used for interferometric analysis, but it requires a lot of experience (e.g. STAMPS). There are also commercial software available. Specialized software should be used for analyzing multispectral images.
- Final results can be elaborated in the GIS environment. QGIS and TNTgis is available free of charge, and commercial packages are also available.

Capacity assessment of the End User shows that there is a need for both employment of qualified staff and upgrade their S/W & hardware facilities so as to support image processing. Training should be also included.

9. Key recommendations & Next steps

The maintenance of GEO-CRADLE network and regional Data Hub is significant for the promotion and further development of the project 'final products'. A study should be performed in order to define the critical actors within the consortium that could support such an action. Alternative options for the funding of the network should be examined including inter alia, other projects or/and associations.

Continuation of GEO-CRADLE activities at national level is depending highly on the available national support frameworks. Another option is to formulate an EU Research and Innovation program on Raw Materials and environmental protection. Major strategies to be considered are: (i) development of a partnership for the submission of a new proposal – continuation of GEO-CRADLE within the framework of any appropriate European call, (ii) preparation of a proposal with the competent authority to be submitted within the framework of a PA call (national level), (iii) seek supplementary funding by professional associations.

Another option for IGME Greece is to compile a proposal in cooperation with the Ministry of Environment and Energy. Such a proposal will have narrow targets and will be related with the pilot case, i.e. monitoring of legal and illegal quarrying activities. The End User understands the efficiency and usefulness of the tools that are or to be developed. Cost efficiency is a critical factor in order to reach final decisions. Monitoring of regional / National quarry activities using Sentinel 2 data is a favorable solution.

The imaging remote sensing sensors only record the earth's surface reflectance of electromagnetic energy of specified wavelengths and do not penetrate the ground. For subsurface structure or mineral deposit to appear on the imagery there must be some visible structure on the surface. Some targets may be expressed at the surface by anomalies of drainage, vegetation, color and fracture pattern that are imaged at the wavelength of visible light or other wavelengths.

It should be stressed that the basic understanding of the mineral mapping from satellite imagery is essential in order to comprehend the significance of the RGB compositions and calculated ratios. It is also important to be aware of the characteristic distortion of various types of imagery and imagery irregularities that could be mistaken for geologic anomalies. However geologists can readily learn enough about remote sensing technology to begin the interpretation of imager (Lintz and Simonett, 1976).

Previous studies indicates that the process of ratio calculation benefits from atmospherically corrected data therefore is essential to performed pre-processing of the satellite images in the specialized software (Mielke et al., 2014b).

To proper map the minerals form the satellite images, the institution should have a spectral library of the interested minerals from the interested location. Spectral library is a collection of spectral reflectance curves, measured by spectrometers. Spectrometers record the energy, usually sunlight, reflected from materials as a function of wavelength. Spectra of materials such as soils, rocks, and minerals should originally be measured in the laboratory using small, pulverized, unweather samples priory to remote-sensing analysis. The spectra are necessary for understanding the relationship between mineralogy and reflectance of the actual surfaces (Hunt, 1980). Sample collection and field spectrometer measurements are also used for verification purposes (Mielke et al., 2012, Mielke et al., 2014b).

After all EO analysis, check field processes should be carried out. The check field should include establishing a set of control points which will be afterwards used for correction of distinguished mineralization zones. The process of satellite images analysis should be widely supported by available other ground-based data, geological maps and mining information.

Repeated analysis performed in a given time period will allow to enhance the geological content of an area and changes in surface conditions and illumination at the different time of exploitation progress.

Exploration for mineral resources is one of many other applications of EO based data. Proper use, processing and analysis of the satellite or air-based images can serve the needs of the investigator and management directly and immediately. Also, unlike agriculture, hydrology or oceanography geological application require less frequent images to fulfill the user needs (Smith 1977).

Although it was proven that multispectral data can be used for mineral mapping, however only hyperspectral data are able to discriminate surface mineralogy correctly as well as provide image of spatial distribution of mine waste materials. EnMAP might in the future be used as main base that helps to improve management of mining sites (Mielke et al., 2014b).

Other types of satellite data (i.e Pléiades 500mm Resolution, RapidEye 5m Resolution Multispectral Images, World View Images with 1 meter resolution) can also be included in a mining exploration program which is to focus on spectral analysis for the detection of "specific target mineral types" that are suspected to be present within the Target Area of Interest in High Concentration.

References

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