MAEGS-15
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15th Meeting of the Association of European Geological Societies

Georesources and public policy:
research, management, environment

16-20 September 2007, Tallinn, Estonia

Abstracts

Edited by Olle Hints & Dimitri Kaljo

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Tallinn, 2007

Contents

Preface

MAEGS-15, the 15th Meeting of the Association of European Geological Societies (AEGS), will be organised by the Geological Society of Estonia in Tallinn, Estonia, on 16–20 September 2007. The meeting is devoted to various aspects of georesources from research and management to environmental and public policy issues.

According to the "Chronicles of Association of European Geological Societies 1975–2000", compiled by Hungarian Professor Endre Dudich (former President of the AEGS), the history of the MAEGS began more than 30 years ago: "*The first impulse was given by Sir Kingsley Dunham of the British Geological Survey, upon the initiative of P. Allen and J.P. Hepworth. In June 1974 he addressed a Circular Letter to 25 European countries, inviting the fellow societies to attend the first Meeting of European Geological Societies at Reading, U.K.*"

MAEGS-1, entitled "Europe from Crust to Core", took place at Reading, U.K., on 8-12 September 1975. Since then 14 meetings of the AEGS have been held in 12 European countries. The scientific focus of these meetings has been rather wide, including geological mapping, evolution of the lithosphere, orogeny and magmatism, geology of the Atlantic, seismic and drill hole investigation, evolution of the Pannonian Basin, Precambrian of Europe, chemical geology, palaeogeography, Carpathian geology, groundwater, and natural hazards.

Although the "hot topics" in Earth sciences have changed during the last 30 years, optimal usage of resources and conservation of the environment have remained among the key issues for all Earth scientists. "Resource issues – towards sustainable use" is one of the science themes of the International Year of Planet Earth, an initiative of UNESCO and IUGS, to which MAEGS-15 is linked.

The 15th Meeting of the AEGS provides an opportunity to get aware of different problems and solutions related to georesources in Europe and worldwide. This abstract volume covers a wide range of topics from regional examples of exploitation and management of georesources to global overviews and future-directed discussions. The conference is followed by a two-day field excursion to acquaint the participants with the geology and mineral resources of Estonia and other Baltic countries.

I wish all participants in MAEGS-15 a pleasant stay in Estonia, fruitful discussions and new contacts during the conference, and sunny days for the field excursion.

Tallinn, August 2007

Rein Raudsep
President of AEGS,
Chairman of the Organising Committee

Programme

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	17:00–17:20		**S. Sabanov, J.-R. Pastarus, O. Nikitin & A. Viil**: Risk assessment of selective extraction of oil shale layers in "Estonia" mine
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	10:10–10:30		**M. Beric & M. Francuski**: Correlation of petroleum-geologiacal characteristics between Velebit and Cantavir structures on the basis of 3D seismics
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19. Sept.	08:30–19:00	**Geological Excursion, northern Estonia** (bus departures National Library parking lot)	
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S. Devoto & E. Castelli: Slope stability in a old limestone quarry interested by a tourist project

S. Kondratjeva: Latvian dolomite – building stone and road construction material

M. Mafteiu, M. Marinescu, R. Maftei & D. Stefanescu: Pollution and environment degradation during the georesources recovery process, revealed using geophysical methods. Case studies in Romania

M. Marinescu, A. Popescu, R. Maftei & M. Matei: The complete management of travertine resources. Case study: Carpinis deposit (Romania)

M. Marinescu: Geomanagement: the meeting between management and geology

M. Radulescu & G. Buia: Natural attenuation of volatile organic compounds as feasible environmental remediation strategy – case study of a complex landfill leachate contaminating the groundwater system

M. Staudt, G. Van den Dool, S. Sapon & J. Leveinen: GIS data management structure for international co-operation projects – an example from the EU LIFE project "Narva Groundwater Management Plan"

V. Strupl: Czech Geological Survey-Geofond: profile of the organization

Y.J. Systra & V.G. Spungin: Postglacial seismic activity of the SE Fennoscandia and Estonia

W. Trela: The Middle/Upper Ordovician phosphorites in the Łysogóry Unit (central Poland) – response to the late Llanvirn sea-level rise

Correlation of petroleum-geological characteristics of the Velebit and Cantavir structures on the basis of 3D seismics

Milovan Beric[1] and Miroslav Francuski[2]

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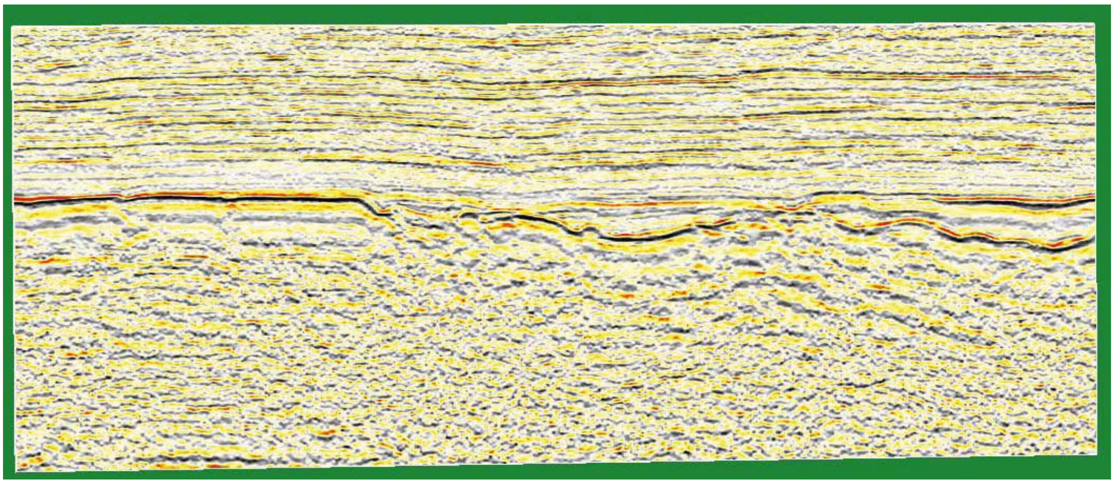
The Velebit and Cantavir structures, known as significant hydrocarbon-bearing formations, are located in the SE part of the Pannonian basin. The Pannonian basin is the region of low deformity, characterized by block faulting, which is located between quite distinct zones created by overthrusting. The recent research based on the well data shows that the region of the Pannonian basin was significantly deformed by the Mesozoic overthrust, and then rented apart from the complex Cenozoic system of normal and transcurrent faulting.

The Velebit structure was formed as a compacted anticline by sedimentation over differently sunk blocks (Fig. 1). Within the core of the compacted anticline, metamorphites (crystalline schists), Mesozoic dolomites and dolomite limestones lie under Tertiary sediments.

Fig. 1. Seismic line.



In the Cantavir area Neogene sediments are underlain by Lower Triassic deposits. Lack of Upper Triassic, Jurassic and Quaternary sediments allows us to conclude that this area was uplifted after the Lower Triassic, without any change until the deposition of Miocene sediments. During the Miocene, outflow of andesite-dacite magma along old faults took place, as well as volcanic material deposition and mixing with Miocene sediments along the edges of the structure. Lack of the Pannonian in the central part of the gas deposit indicates that, at that time period, the Cantavir structure was subjected to local emersion, and finally, during the Pontian, the whole structure was flooded by sea.

The Cantavir structure was not affected by radial tectonic movements. The mild anticlinal (dome) form of the Lower Pontian sediments depends on the form of the Neogene footwall, and also of Neogene sediments deposited over the Neogene base.

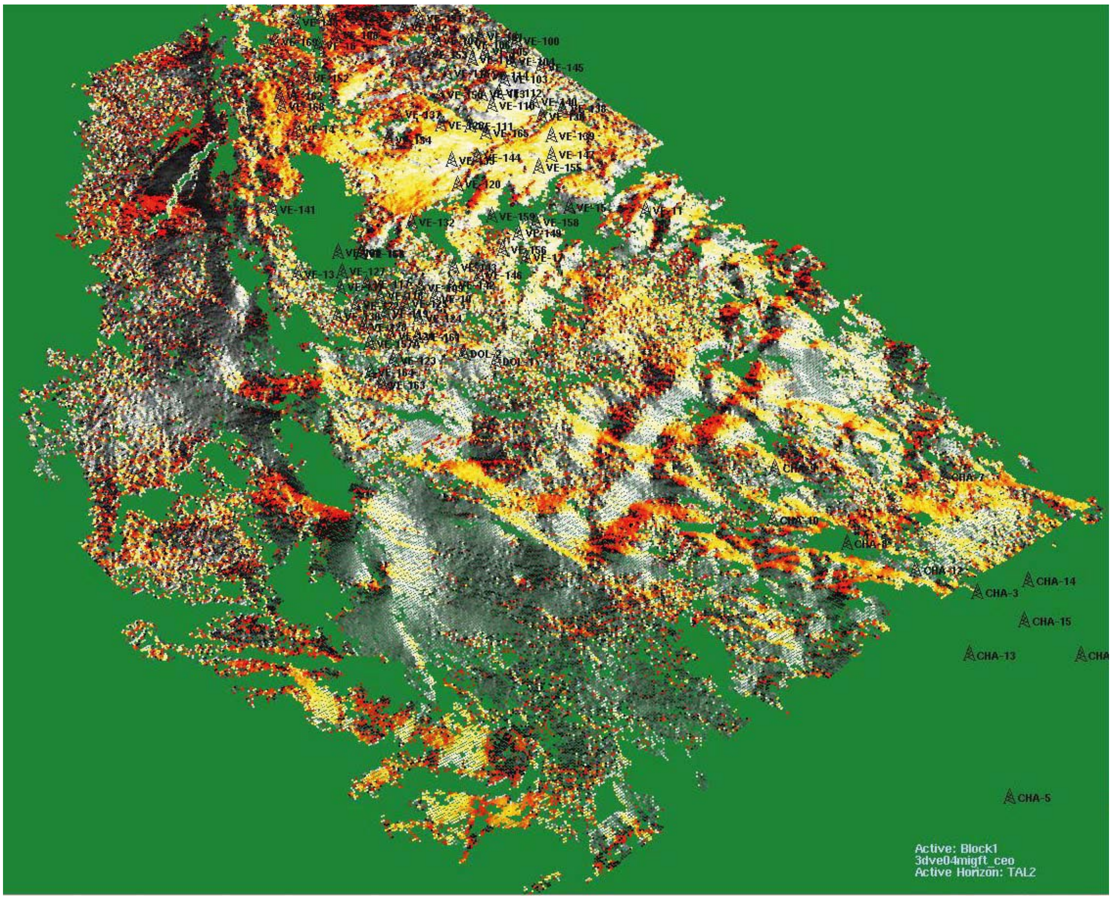


Fig. 2. Seismo-geological model.

In order to define structural-tectonic and lithostratigraphic relationships of the mentioned structures correctly, interpretation of detailed 3D seismic data was performed. According to the analysis of the obtained results, it was defined that, taking all aspects into consideration, the Velebit structure is very convenient for hydrocarbon accumulation (Fig. 2). This was verified by hydrocarbon reserves, which are several times greater in that structure.

Subsidence hazards connected to quarrying activities in the karst area: an up-dating of the Moncalvo Sinkhole Event (Piedmont, NW Italy)

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[2] Politecnico di Torino, Torino, Italy; adriano.fiorucci@polito.it, bartolomeo.vigna@polito.it.

Gypsum is an important raw material for constructions and other industrial sectors. In the last few years, gypsum exploitation has developed due to the high demand on the domestic and international market. In Piemonte (NW Italy), main gypsum bodies occur in the Monferrato area where large open pits and underground quarries (set out on regular superimposed sublevels) are located.

The gypsum-bearing formation cropping out in this area shows typical geological, structural and hydrogeological features, which influence the quarrying and relative interaction with natural phenomena, human activities and land use.

Gypsum bodies show an extension of a few metres up to several hundreds and more kilometres. Their thickness is quite unsettled, but it can reach over 100 m with an average value of 30–40 m. They belong to the Messinian "Gessoso Solfifera Formation", lately named "Complesso Caotico di Valle Versa" in the Monferrato area, according to the recent geological map (Dela Pierre et al. 2003). The Messinian sequence represents marly-clayey facies, including large bodies formed by several metres thick gypsum layers separated by interbedded strata, mostly composed of marls. These strata range in thickness from a few centimetres to some decimetres. Locally, a few system faults occur in gypsum deposits and, sometimes, they are marked by a marly filling. Due to the high solubility of gypsum in the presence of fluent water, it is possible to recognize evidences of Quaternary karst activity (caves, potholes, pipes).

Gypsum karst has considerable influence on mining operations, mining operations in turn can produce strong impact on gypsum karst, particularly when water pumping is involved and quarrying interferes with the local hydrogeological setting (increase in flow velocities and dissolution rate, lowering of the water table, breaching of artesian confinement, draining of surface flows, extension of drawdown cones). Gypsum karst is much more susceptible to human impact than carbonate karst, particularly when changes in groundwater circulation are induced. As a matter of fact, in exploited areas it is possible to observe ground subsidence and collapses.

In Monferrato, a specific case of interaction between quarrying activity and geological, hydrogeological and territorial setting is represented by the event of water inrush in the Moncalvo underground quarry, associated with the development of a surface sinkhole.

In Moncalvo, traditional methods of exploitation – rooms and pillar and blasting techniques – have been replaced by new technology represented by "road header" as continuous mining machinery. The roadheader allows both a perfect profiling of smooth and regular opening walls and protection of the surrounding gypsum from the typical damages of blasting methods, favouring general stability (Fornaro et al. 1996). This quarry is organized on two superimposed sublevels settled in parallel "development drifts", following the dip of the gypsum beds, and "exploitation drifts", following the strike of gypsum strata (Bonetto 2006). The development and exploitation drifts in the production panels do not intersect each other orthogonally as in a blasting exploitation, but take a "lozenge pattern". All the quarry levels are reachable through a helical ramp, which can be used by lorries.

In February 2005 an inrush event took suddenly place during excavation works due to the cut off of a karst cave, still involved in active water flowing. As the mining face intercepted the cave, a large amount of water (about 60 000 m^3) and terrigenous marly sediments flowed into the quarrying drift submerging the road header. As a consequence, a funnel-shaped collapse formed at the surface, showing a minimum depth of 10 m and maximum diameter of about 20 m (Bonetto & Fornaro 2005). Most of the second quarrying level was flooded by water, as well as part of the first level. In order to reduce and stabilize the water inflow into the quarry, a pump was installed at the second level.

Besides safety restoring operations, surface and subsurface investigations were carried out to understand better the underground water circulation in gypsum, origin and quality of water inflow and triggering mechanisms of the sinkhole event. Subsurface exploration was conducted by means of borings and geophysical methods using electrical and seismic refraction tomography that allowed reconstruction of the local geological setting and assessment of the overburden thickness. A local rain gauge and some piezometers (inside and outside the quarry area) were installed, so that continuous measurements of the groundwater table could be carried out and variations in the water level related to rainfall and pumping activity could be monitored.

In October 2005, a weir was installed close to the mining face where inrush occurred: water level, water temperature and electrical conductivity were continuously measured by means of a digital data logger. On account of the lowering of the water level in the drift, the karst cave behind the mining face, responsible for the inrush, was scoured. Three main interconnected karst conduits and a room were discovered, but just two of them could be inspected; in particular, it was observed that one of the conduits ended where the funnel-shaped collapse was formed at the surface. During scouring of the karst conduit, three separate water inflows were recognized and analysed by means of sample collection and chemical-physical laboratory tests.

The data collected show a strong connection between the pumping of the water inflow in the quarry and piezometric measurements in some piezometers, whereas other ones show an independent behaviour. On the basis of groundwater table monitoring in the piezometers network, two main aquifer systems have been assumed: a water flow in fractures and a main karst active circuit not connected with the surface that represents a general collector for groundwater flow. Furthermore, from the data furnished by the local rain gauge it has been observed that external piezometers are connected neither with main aquifer systems nor with rainfalls.

Chemical and physical analysis of the three main water inflows sampled in the karst circuits, revealed different water quality, particularly concerning the nitrate-bearing ratio and the redox-potential (Eh). Such parameters suggest a different origin of the water flowing into the karst circuit, both superficial (high nitrate-bearing ratio and positive redox-potential) and deep (low nitrate-bearing ratio and negative redox potential) sourcing.

Actually, total water inflow in the quarry shows a discharge of about 8 l/s as regards the karst circuit and 5 l/s as regards water flow in fractures (already present before the inrush), whereas the sinkhole has been refilled to assure public safety. The monitoring of the quality and quantity of the water inflow is still in progress, as well as the pumping activity in the quarry. Unfortunately the water pumped is unsuitable for irrigation purposes due to high values of TDS, electrical conductivity and sulphates; therefore it is immediately directed to the drainage system.

Monitorings and investigations are still in progress and a better definition of the territorial and geological setting is necessary for future mining planning.

Bonetto, S. 2006. Il gesso: da risorsa economica a patrimonio culturale del Monferrato. Aggiornamento tecnico, metodologie operative e ipotesi di riuso dei siti di cava dimessi. Doctorate Thesis, Politecnico di Torino. Unpublished.

Bonetto, S. & Fornaro, M. 2005. Subsidence events related to natural conditions and gypsum quarrying activity in the Monferrato area (Piedmont, NW Italy)". MAEGS14 – 14th Meeting of the Association of European Geological Societies, Torino, 19–23 September 2005, ISBN 88-7479-018-X. (Abstract).

Dela Pierre, F., Piana, F., Fioraso, G., Boano, P., Bicchi, E., Forno, M.G., Violanti, D., Balestro, G., Clari, P., D'Atri, A., De Luca, D., Morelli, M. & Ruffini, R. 2003. Note Illustrative della Carta geologica d'Italia alla scala 1:50.000; Foglio 157 Trino. Settore Studi e ricerche Geologiche – Sistema Informativo Prevenzione Rischi – ARPA, Litografia Geda, Nichelino 2003.

Fornaro, M., Savasta, G., Accattino, G. & Amalberto, S. 1996. Progetto di una moderna coltivazione di gesso in sotterraneo ed inserimento ambientale dell'attività estrattiva. IV Congr. Minerario Italo-brasiliano, Canela (Brasile), Ed. EGATEA Porto Alegre, 104–114.

Preliminary GIS-based analysis of regional-scale VMS prospectivity in the Skellefte region, Sweden

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The objective of this paper is to present preliminary results of VMS prospectivity mapping in the Skellefte region, which is a recent project in the Geological Survey of Sweden (SGU) involving application of GIS to analyse and integrate various geosciences datasets in predictive mapping of mineral prospectivity. The Skellefte region, situated in the northern part of Sweden, consists mainly of the Svecofennian ca. 1.90–1.85 Ga supracrustal sequences and associated intrusive rocks (Fig. 1). The region is extremely rich in mineral deposits and has especially been regarded as one of the largest early Proterozoic VMS districts in the world.

For preliminary regional-scale mapping of VMS prospectivity, we applied weights-of-evidence (WofE) modelling (Bonham-Carter et al. 1989) in order to (a) determine useful spatial evidences (i.e., having positive spatial association with the VMS occurrences) and (b) create a predictive map of VMS prospectivity. The WofE method involves the updating of prior probability of deposit occurrence using conditional probability of deposit occurrence to derive posterior probability of deposit occurrence. Two conditional probabilities of deposit occurrence are estimated, W+ and W–, given presence and absence, respectively, of spatial evidence. The magnitude of the difference W+–W–, called contrast (C), represents the degree of spatial association between deposit occurrence and spatial evidence. Spatial evidences with positive and statistically significant contrast (or studentized C) are considered useful for mineral prospectivity mapping. For such useful spatial evidences, predictor maps containing values of W+ and W– are created. Predictor maps are integrated with prior probability of deposit occurrence under assumption that predictor maps are conditionally independent of each other with respect to deposit occurrences.

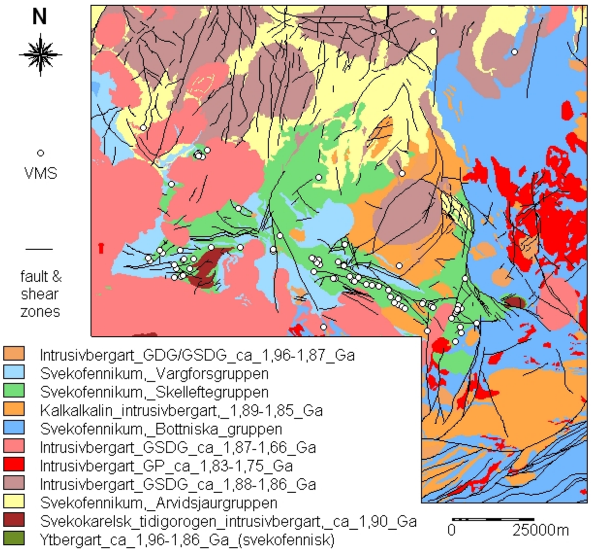

Fig. 1. Simplified geological map, Skellefte region.

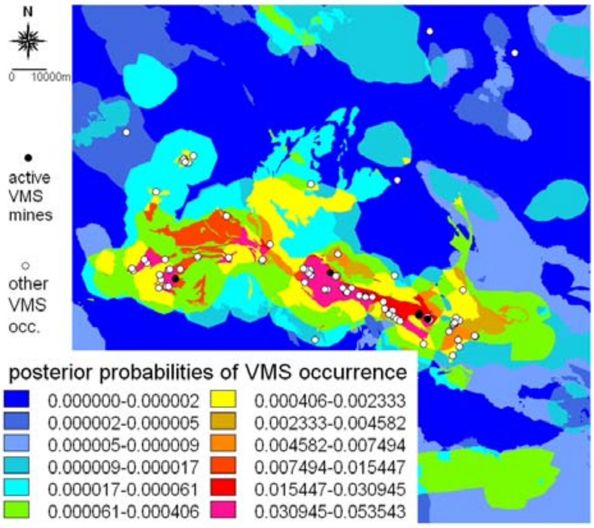

Fig. 2. Preliminary regional-scale VMS prosperity map.

The following regional-scale features were initially considered in VMS prospectivity mapping: (a) bedrock geology, (b) contact between the Skellefte Group (SG) and the overlying Vargfors Group (VG), (c) shear zones and (d) geochemical anomalies. Shear zones have either been mapped in the field or interpreted from aeromagnetic data. In this work, the shear zones were categorized into six classes according to their trends (WNW=270–300º; NW=300–330º; NNW=330–360º; NNE=0–30º; NE=30–60º; ENE=60–90º). Geochemical anomaly maps were derived by kriging of Cu and Zn concentrations in till samples. For WofE modelling, we used locations of 77 VMS occurrences (closed mines and prospects) as training deposits and locations of five VMS occurrences (active mines: Kristineberg, Maurliden Västra, Renström Västra, Petiknäs Södra, Petiknäs Norra) as validation deposits. Via point pattern analysis (Boots & Getis 1988) of the VMS occurrences, it was found that 100 m is the best unit cell or pixel size to represent each location of VMS occurrence as one, and only one, deposit.

The spatial evidences found useful (i.e., according to magnitude of studentized C; Table 1) for regional-scale VMS prospectivity mapping are: (a) members of the SG, (b) proximity to SG–VG contact (c) proximity to NW-trending shear zones, (d) proximity to WNW-trending shear zones, (e) proximity to ENE-trending shear zones, (f) >70th percentile Cu values in till samples and (g) >50th percentile Zn values in till samples. Of the different members of the SG, felsic volcanics are more important spatial evidences than mafic volcanics and sediments. This is consistent with field knowledge of VMS deposits in the area. Proximity to the VG–SG contact is important because most of the VMS occurrences are found in felsic volcanics in the SG underlying the VG. Proximity to WNW- and ENE-trending shear zones is more important spatial evidence than the NW-trending shear. These three sets of shear zones, however, probably represent the same tectonic regime coeval with VMS mineralizations. Anomalies of Cu are more important spatial evidence than anomalies of Zn, probably because the former element is less mobile than the latter element in weathering conditions in the area.

Results of WofE calculations were used to create binary predictor maps. Prior to combining the predictor maps, the three units of the SG were aggregated into one binary map and the weights were re-calculated. In addition, binary predictor maps for proximity to WNW- and ENE-trending shear zones were combined into one binary predictor map because they show conditional dependence with respect to the training deposits. The derived posterior probability map was then classified into a predictive map of regional-scale VMS prospectivity (Fig. 2). The performance of the predictive map was evaluated according to guidelines discussed by Agterberg & Bonham-Carter (2005). The results indicate that if 10% of the area is considered exploration targets, based on the upper 10 percentile posterior probabilities, then there is at least 85% chance of finding an undiscovered VMS deposit. All the five active VMS mines, which were assumed to be undiscovered deposits, are delineated within less than half of the exploration target areas. The preliminary results are promising. Further work, however, will be carried out to integrate other regional-scale datasets such as airborne magnetics and radiometrics, etc.

Table 1. Quantified spatial associations between spatial evidences and VMS occurrences.

Spatial evidence (binary pattern)	N(B)^a	N(B$\cap$D)^b	WofE parameters^c					
			W+	S(W+)	W-	S(W-)	C	Studentized C
Bedrock:								
Felsic volcanics (SG*)	31952	42	2.0118	0.1544	-0.7127	0.1690	2.7245	11.9020
Sediments (SG*)	5006	10	2.4310	0.3165	-0.1276	0.1222	2.5586	7.5415
Mafic volcanics (SG*)	8879	11	1.9525	0.3017	-0.1337	0.1231	2.0862	6.4024
Proximity (0.0–6.6 km) to VG–SG** contact	87322	57	1.3112	0.1325	-1.1256	0.2236	2.4368	9.3756
Proximity to shear zones:								
NW (0.00–7.17 km)	174214	41	0.2906	0.1562	-0.2525	0.1667	0.5431	2.3774
WNW (0.00–5.82 km)	131207	51	0.7925	0.1401	-0.7293	0.1961	1.5218	6.3144
ENE (0.00–6.85 km)	174409	55	0.5833	0.1349	-0.7443	0.2132	1.3276	5.2621
Till anomalies:								
Cu (>70th percentile)	133263	50	0.7572	0.1414	-0.6848	0.1925	1.4420	6.0372
Zn (>50th percentile)	220384	50	0.2540	0.1414	-0.3474	0.1925	0.6014	2.5179

*SG = Skellefte Group; **VG = Vargfors Group; ***a*** = number of pixels in binary pattern; ***b*** = number of pixels in binary pattern with VMS occurrences; ***c*** = refer to Bonham-Carter et al. (1989) for explanations of these parameters.

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Slope stability in an old limestone quarry interested by a tourist project

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The old Sistiana quarry (northeastern Italy) has been in the centre of a tourist and environmental restoration project due to its great extension, proximity to the sea and the value of its surroundings. The project entails the creation of a small Istrian–Venetian town and the implementation of safety measures on the quarry slopes. The poor quality of rock masses, considerable steepness of the slopes and diffuse use of mines during quarrying activities called for the re-profiling of slopes via pre-splitting.

The aim of the paper was to assess the stability improvements by comparing the results of the SMR system applied to current slopes and the stability percentages determined through the application of the SSPC method to the future re-profiled rock mass.

NGOs, local people and uranium exploration in Finland. The anatomy of a new challenge

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The global climate warming returned nuclear power in the agenda. Many countries, including Finland, have decided to construct more nuclear power plants. They will need uranium, and its price has risen in the international market. There is a new uranium exploration boom going on.

Finland has several promising uranium showings. It is also a politically and economically stable state with good infrastructure, and basic geodata, attracting foreign companies to explore uranium all over the country. However, a strong campaign has arisen against it. Here we will examine the anatomy of this challenge and how to try to resolve it.

When foreign companies came to Finland, and started to request claim reservations and claims, local people were not previously contacted and informed. When they got aware of this process, the lack of information caused fear and local resistance. Local environmental activists and political leaders channelized this non-satisfaction to local, organized movements. Media started to follow them and gave much attention to uranium exploration, often based on false information. Strong anti-uranium movements developed in northern, eastern and southern, but not in central Finland. They formed a nation-wide coalition, strongly identified with the anti-nuclear movement, Green Party, and Finnish and international environmental NGOs. They received also adhesion of former anti-conservationist sectors, such as landowners, local politicians, and entrepreneurs. The uranium exploration boom and strong movement against it surprised the Ministry of Trade and Industry, which found itself in a completely new situation, and with a controversial role on the issue. This has caused more confusion and misinformation both in the mining industry and NGOs. In fact, most of the environmentalist criticism is directed towards the Ministry.

The weak public awareness of geology and exploration is one of the causes of this situation. There is much confusion about what uranium ore, a claim reservation, claim, and mine are. They are all mixed, and there is a general belief that exploration will automatically lead to a huge open-pit uranium mine that would destroy everything around it, causing radiation and polluting groundwater. The movement wishes to stop exploration activities in their beginning and does not know that only 1 of 1000 exploration campaigns can lead to a mine. However, the terminology used by mining industry and law is another problem. The term “claim” in Finnish (valtaus) means also occupation or conquest, and this gives a kind of militaristic meaning to this term.

How to deal with this situation? The key-word is openness. Local people should be contacted and informed about the exploration activities, i.e., what geologists and the company intend to do in the region. Often local residents do not know that they live in a uranium-bearing area and should be informed about it. Radiation measurements around their houses have been acknowledged, tranquilizing them. After local residents, NGOs can be called for a discussion, opening a channel for a dialogue. A local newspaper should also be informed and given an interview. In all these contacts, information on geology and mining industry should be given. Companies can support local initiatives on eco-/geotourism. Exploration activities and claim requests should be avoided in densely populated and nature conservation areas. All this creates a good image for a company.

Much expectation is deposited on the reform of the mining law, which should be a kind of compromise between the requirements presented by the industry and environmentalists. The Finnish term for claim should be changed for a more neutral. However, all those difficulties can make Finland unattractive for new mining investments.

The use of boulders in urban landscaping at Espoo, Finland

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Glacial, erratic boulders are a natural and prominent part of Finnish landscape. They have also had an important role in national traditions. Nowadays, they are used in landscaping in many Finnish towns. Here we present some examples from Espoo, located in the Metropolitan region of the capital, Helsinki.

In Espoo, boulders are found also in constructed areas. Boulders are preserved when building in their surroundings, and are not removed or destroyed. Many of them can even be protected as geosites and integrated in interpretative trails. However, some of the urban boulders are not erratic because they were not transported to a place by a glacier, but installed by man. The aim of these installations is aesthetic and practical. Boulders are used to outline parking areas and decorate the place at the same time. One of the examples is the parking area of a famous furniture shop. Boulders were installed along lines towards a crop surrounded by forest. In residential areas, boulders are also used to avoid car traffic in walkways. This practical application has been used since the 1960s.

When used only in landscaping, boulders are installed in groups, half-immersed into the ground, and surrounded by well-rounded glacio-fluvial pebbles. These examples can be found at Leppävaara, Espoonlahti and Kilo, where boulders decorate margins of bicycle ways, and a road under a bridge. Those have been planned and installed by private planning companies, licenced and coordinated by municipal authorities. This kind of rock installation is also used outside a nearby shopping centre. There, strongly angular boulders extracted directly from the bedrock were installed in a “cubistic” fashion. A similar, but more massive example surrounds a gas station at Bemböle.

These installations are composed of rough, uncut boulders consisting mainly of K-feldspar granites, but also amphibolites, migmatites and gneisses are used, reflecting the Precambrian bedrock of southern Finland. The dimensions of the boulders are usually around 0.5–1 m. Their rough, brutal naturality reproduces a primitive, monolithic aesthetics that fits well with Finnish landscape and Finns’ minds. The Chinese call it “ugliness” in stones, which has a strong aesthetic and artistic value for them. The boulders described here are examples of applications of geology and *geoaesthetics*, bringing geology and stonescaping closer to people in their everyday lives.

Origin and composition of chert and chertified phosphate nodules in the Eocene Thebes Formation, Gebel Atshan, Red Sea Coast, Egypt

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The Lower Eocene carbonate rocks of the Thebes Formation in Egypt are highly intercalated with chert bands, nodules and concretions. The studied section in Gebel Atshan near Quseir town, Red Sea, contains some carbonate nodules as well as chertified phosphate nodules. The chert and chertified bodies occur in various forms such as the nodular, banded, irregular masses, and continuous and discontinuous lenses. They display various shades of white, grey, brown and black. The limestone attains a porcelaineous nature when subjected to silicification.

Petrographically the chertified phosphate nodules consist of phosphatic pellets, coprolites and bone fragments with sponge spicules, crinoids, echinoids, brachiopods and some benthic and planktonic foraminifera cemented by cryptocrystalline silica. Some chert concretions and nodules enclose spherical carbonate pebbles and fragments. The examination by X-ray diffraction and electron scanning microscope authenticates the complicated paragenetic history of these nodules. Syngenetic, early diagenetic and late diagenetic processes have been encountered.

The rhythmic alternation of limestone and chert (bands and nodules) indicates that they were formed in shallow marine environment with high sea-level fluctuation.

Lithuanian mineral resources and their usage: today, future and problems

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Mineral resources have been, are now, and will be one of the main factors of the economic and social progress of our societies. The 20th century was the century of practically global industrialization, unprecedented consumption of subsurface resources, and impact on the environment. Society cannot survive without using natural resources, therefore their extraction is inevitable. Satisfaction of the demand for mineral resources and the impacts of extracting minerals on the environment are of increasing public concern. In accordance with the spirit of the Rio Declaration, many countries in the world are now committing to the concepts of sustainable development (based on three dimensions – economy, environment and needs of society) and have taken initiatives to reconsider their national mineral resource management policy and to harmonize it with this conception. The sustainable management of mineral resources implies: sound geological knowledge; implementing the international policy and measures, harmonization of national legislation concerning access to mineral extraction and globalization of the resource market, irrespective of world's political and state arrangement; proper implementation and strict enforcement of legislation; preparation of regional sustainable development plans, development of strategies at regional and transnational levels;

and providing educational awareness of the problems of living and working in environmentally sensitive areas; sharing the experience of mining industry (which operates under strict environmental requirements); communicating with the local community (bridge from emotion to knowledge). Much effort has been made in the fields of research, legislation and education, however much work remains to be done. Due to the lack of objective and neutral information, the extractive industry is often approached negatively, therefore it is important to change this picture.

The subsurface of Lithuania hides a considerable amount of mineral reserves, mainly construction mineral materials or raw materials for their production (Gasiūnienė 1998). However, by the amount of their extraction and consumption as well as their value in the world, they are the most significant and main mineral resources (after energy resources). The most important mineral resources explored at the expense of the state budget in the period of 1940–1990 provided a reliable basis for mineral commodities in the country. In the meantime, only as much as 55% of earlier explored mineral deposits are under operation, whereas the rest of them are out of use (RP 2002).

In Lithuania, 17 kinds of mineral reserves/resources have been explored to various degree of detail. Nine of these (limestone, dolomite, sand, gravel, clay, chalky marl, peat, sapropel and oil) are under exploitation, and the exploitation of gaize (opoka) was suspended in the 1990s.

Changes in the national economy during the last two decades have altered the policy of the investigation of mineral resources so that only initial investigation is financed from the state budget, while the prospecting and exploration of usual mineral resources are financed by the customer, with the exception of the works related to the prospecting and exploration of new oil deposits, which are partly covered from the state budget. During the last decade the market laws have forced the enterprises to explore at their own expense new deposits located nearer to the user with the purpose of reducing the transportation costs.

According to the legal acts, only the reserves explored in detail can be used. Permission for the utilization of mineral resources and cavities can be given to legal entities by the Government of the Republic of Lithuania or by the Geological Survey, depending on the kind of resources, their quantity and potential impact on the subsurface status of other states. Currently, the permits (licenses) to consume underground reserves in 375 mineral deposits have been issued to 229 enterprises (GSV 2002).

Owing to significant changes in the construction sector, increased import of the construction materials, growing prices of energy resources, lack of funds for modernization of energy-consuming technologies, increased transportation expenses, decrease in local demand and limited possibilities of the external market, the extraction of mineral resources decreased by over seven times in the period of 1990–1996, but increased insignificantly and became stabilized later. From 2001 the extraction of main kinds of mineral resources has increased permanently. In 2006 the total amount of extracted hard mineral commodities made up 11.1 million cubic metres, of peat – 0.4 million tonnes, of oil – 0.2 million tonnes. The extraction and recultivation of the damaged areas are carried out according to the project of use. Today, 22 200 ha of land (0.34% of the Lithuanian territory) is assigned to enterprises for the extraction of mineral resources, of which the land for peat production makes up the largest part. About 13 600 ha (0.2% of the Lithuanian territory) has been damaged by mining.

At the present time the interests of the state (and enterprises) and landowners often conflict as to the use of mineral deposits. In the nearest future the negative outcome of this process can affect the development of state economy, therefore harmonization of the legal basis is required.

All mineral commodities, with the exception of oil, are mined only in open-pit mines and quarries. The depth of gravel, sand, clay, peat and dolomite quarries usually amounts to 6–12 m, that of limestone and opoka (gaize) – up to 15–20 m, only the deepest quarry where Triassic clay is extracted is as much as 50 m deep. The thickness of the overburden in all quarries ranges from 0.5 m to 10 m. The overburden, useful mineral resources and tailings all constitute the rocks of our daily living environment, inert from the chemical point of view. Usually overburden rocks and tailings are utilized for recultivation of the excavated area (excavation void), therefore there are no mining waste facilities, with the exception of only waste heaps in 2–3 quarries. The groundwater level has lowered due to self flowing or pumping up in several quarries only (peat, limestone, dolomite, sand). So, in Lithuania there are no “hot spots” associated with quarrying activity. Only the abstraction of groundwater from limestone and dolomite quarries, and the technology of the extraction (explosions) could be classified as factors causing some adverse impact on the environment. These impacts are monitored by enterprises according to groundwater monitoring programmes.

Though deposits of solid mineral resources in Lithuania often have different geological structure and are found in different natural conditions, the mining poses relatively small threat to the stability and integrity of geosystems. The impact is most often short-term and can be compensated by rational and effective recultivation, which sometimes can even improve the quality of the environment.

Depending on the geological structure, Lithuanian regions are unevenly provided with the main mineral reserves/resources. The problem of possible depletion of many mineral resources will not be urgent to us and our descendants, because these resources will last for some centuries, except for low-decomposed peat, Devonian clay, monomineral quartz sand and, of course, oil (resources that will last for less than 100 years are considered as depleted ones).

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Surface weathering of rapakivi granite outcrops – implications for natural stone exploration and quality

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Rapakivi granites are defined as “A-type granites characterized by the presence, at least in the larger batholiths, of granite varieties showing rapakivi texture” (Haapala & Rämö 1992). A typical feature of rapakivi granite is the distinct surface weathering of outcrops, so-called grusification (Kejonen 1985). This plays a central role in natural stone explorations and quality evaluations (especially regarding the appearance and soundness of stone). Our aim is to discuss the implications of surface weathering of rapakivi granite for the exploration of natural stone and its quality.

According to the standard EN 12670, natural stone is defined as a piece of naturally occurring rock. A natural stone product is a worked piece of naturally occurring rock used in buildings and for monuments. The suitability of a rock for natural stone production is controlled by several quality requirements, which can be divided into two main groups: (1) geology-based and (2) non-geological (Selonen et al. 2000). The aesthetical properties of the stone are critical when choosing natural stone for architectural use, e.g. as exterior cladding or interior flooring. The appearance of the stone is defined by its colour, structure and pattern (e.g. Bradley et al. 2004).

A natural stone deposit should have a suitable pattern and spacing of fractures for extraction. The general character of the fractures (such as microfractures, fillings, openness, etc.) is of importance while assessing the soundness of the stone. Quarry blocks can be extracted by exploiting natural fracture directions in the bedrock; hence regular fracture patterns are to be favoured.

The study is based on an extensive exploration for natural stone in the whole of the Wiborg rapakivi granite batholith in southeastern Finland (Härmä & Selonen 2000; Härmä 2001; Härmä 2003a, 2003b). The explorations were performed as regional-scale field mappings and as prospect-scale site investigations. In the regional-scale field mappings the colour, texture, homogeneity and soundness of the rocks were visually observed in outcrops and in specimens. A total of 1570 field observations were made and 341 samples were collected using a hand-held diamond saw. Furthermore, 341 samples were collected especially to get an impression of how weathering affects the colour of rapakivi granites and to recognize the genuine colour of rock.

The Wiborg batholith is composed of different rapakivi granite types: wiborgite, pyterlite, even-grained rapakivi granite, porphyritic rapakivi granite and porphyry aplite. Wiborgite ("normal rapakivi") is the main type. The rapakivi granite weathers quite easily on surfaces of outcrops, but also randomly along subvertical and subhorizontal fractures. The weathering studies focused on wiborgitic and pyterlitic rapakivi granites, because these weather more easily than other rapakivi varieties. Weathering of outcrops in the even-grained rapakivi granite has not been observed. The study also focused on the uppermost part of rapakivi granite outcrops and on early stages of weathering phenomena of the granites. Wiborgite and occasionally pyterlite weather from the upper parts of the outcrops down to an approximate depth of one or two metres. The colour of the rapakivi granite on the outcrop surface represents almost invariably the colour of a weathered rock.

The fracture pattern in the rapakivi granites is orthogonal, with fractures both open and closed. The main fractures are often open. On average, the outcrop fracturing is sparse, with the spacing of the horizontal and vertical fractures of 2–3 m. Predominant subhorizontal fractures and also subvertical fractures can be observed in all samples and drill cores. Subhorizontal microfractures can be seen very clearly in resign impregnated samples and thin sections. These microfractures cut through all mineral grains and ovoids in the samples and do not follow the boundaries of the grains or ovoids. Subvertical microfractures can be seen also in K-feldspar ovoids. Along these microfractures alterations of K-feldspar have been observed. This alteration of K-feldspar could be an early stage of the weathering of rapakivi granites towards a more explicit chemical and/or mechanical weathering process. The microfractures of rapakivi granites are probably produced by tensions in the crust caused by tectonic movements.

Because of the strong surface weathering and staining the colour determination of rapakivi granite was difficult at the outcrop surface, whereas the texture was easy to define. The macroscopic soundness was not a major problem in the evaluation because of the generally wide-spaced fracturing of the rapakivi granite in the study area. In contrast, the microscopic soundness is heavily influenced by the surface weathering in the upper parts of the outcrops. Due to strong surface weathering in the Wiborg rapakivi granite batholith the core drilling is an essential method assisting determination of the colour, but it is the most expensive method. Hence, a cheap and easy to use sample drill for shallow drilling should be developed. Furthermore, alternative methods (e.g. geophysical) for studying colour variations in rock are needed.

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Distribution of heavy metals in the soils of Iaşi city and its surroundings

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Objectives

The main objective of this study is to pursue a systematic investigation concerning the content and distribution of Zn, Cu, Fe, Mn, Pb, Ni, Cr, Co and Cd, the heavy metals commonly found in urban soils due to anthropogenic activities.

The results will contribute to the assessment of soil quality and prognosis of the contamination level, including the identification of the anthropogenic polluting sources in the Iaşi city area. The regions considered in this paper are part of a more detailed study that covers a perimeter of approximate 16 x 16 km2 (Iaşi city and its surroundings).

Environment

Iaşi, the second largest Romanian city, is an important economic centre in Romania. It has an active trade in metals, medical drugs, textiles and clothing, banking, wine and preserved meat. The city has also become an important IT sector centre, with five state and three private universities. Iaşi is also an important regional commercial centre.

The total population of the Iaşi metropolitan area is about 400 000 inhabitants, with a density of 149.6 inhabitants/sq. km.

The soil cover in the studied areas consists of the following types: Mollic Fluvisols, Gleyic Fluvisols, Stagnic Fluvisols, Calcic Phaeozems, Chernozems, Calcic Chernozems, Vermic Chernozems, Eutric Regosols, Mollic Technosols, Siltic-Clayic Technosols, Hortic Anthrosols and Eutric Anthrosols (WRB–SR-2006).

Methods

Topsoil samples were collected on a grid of 500 m, from a depth of 0–25 cm, with a 25 cm long hand sampler. This study concentrated on 300 samples from the agricultural soils and forests covering the NE and SE areas of the survey perimeter. The samples weighing between 1.5 and 2.5 kg were dried and sieved to <1 mm fraction and then randomized and analysed by Atomic Absorption Spectroscopy (AAS). The pH was also determined by using a Corning M-555 pH/Ion Meter. External check was performed on 18 samples (10%) by X-Ray Fluorescence Spectroscopy (XRF) at the University of Vienna, Austria and by AAS at the University of Katowice, Poland.

Results

The heavy metal contents (Table 1):

- range between the normal values for soils: Fe, Mn, Co;
- in some cases, surpass the limit of intervention: Zn, Cu, Pb, Ni and Cr;
- show significant positive correlations for the following pairs of chemical elements: Zn–Cu, Zn–Pb, Cu–Co, Fe–Mn, Fe–Co, Fe–Ni, Fe–Cr, Mn–Co, Pb–Cd, Pb–Ni, Pb–Cr, Co–Cr, Ni–Cr and significant negative correlations for Cu–Cd and Cd–Co. The soil pH varies between moderately acid and strongly alkaline.

Conclusions

Heavy metal contents are contrasting, ranging from normal to high values even in the same profile. The current work has established possible anthropogenic geochemical Ni, Cu anomalies for the entire preliminary research area and a localized one for Cr and Pb. The possible causes of the anomalies could be plastic industry, steel works, refractory bricks factories, traffic, coal combustion, waste disposal and incineration, fertilizers, insecticide and geogenic dust.

Table 1. Qualitative parameters of soils in Iaşi and its surroundings (ppm)

Element	Range interval		Average	Normal values*
	Minimum value	Maximum value		
Zn	40.1	1620.3	86.446	100
Cu	11.6	308.3	40.227	20
Fe	7118	32586	19282,460	35000
Mn	50	1669	631.375	900
Pb	4.5	209.8	18.503	20
Cd	0,08	2.368	0.447	1
Co	5.1	14.3	9.336	15
Ni	13.5	349.6	39.785	20
Cr	6.6	591.6	28.589	30

*As of Romanian legislation

Fluid inclusion studies in search for hydrocarbons in marine and mountain regions – the Baltic Sea and Carpathian cases

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Inclusions found in different minerals as, e.g., quartz, may act as indicators of fluid migration (at that, of hydrocarbons) and for this reason may be used in search for hydrocarbons.

The aims of the paper are to show characteristic features of fluid inclusions (FI) in quartz cement and quartz crystals and to propose an interpretation of the results of the isotope, microthermometry and fluorescence studies in the context of fluid evolution and formation of rocks.

Two cases from Poland are presented as the examples and discussed: the Baltic Sea region (N Poland; Jarmolowicz-Szulc 2001) and the Carpathians (SE Poland and W Ukraine; Jarmolowicz-Szulc & Dudok 2005). Both areas have different specifics.

In the former region quartz occurs in the form of cement in Cambrian sandstones revealed by the boreholes drilled in the Polish segment of the Baltic Sea. The hydrocarbon inclusions (white-blue to yellow in ultraviolet light) correspond to light and mature oil and point to the late hydrocarbon migration to the reservoir.

In the latter area, the so-called “Marmarosh diamonds” represent the quartz containing different types of fluid inclusions, the aqueous (AQFI) and hydrocarbon (HCFI) ones. Hydrocarbons are different. They oscillate from pure methane, occasionally with some nitrogen admixture, to heavier hydrocarbons (oil). The presence of these differentiated hydrocarbons suggests that oil-bearing regions are situated westwards, while those richer in gas lie eastwards.

The fluid inclusion and isotopic studies of both quartz cement and quartz crystals point to hydrocarbon migration and the character of the palaeofluids responsible for the mineral crystallization. The areas of the occurrence of hydrocarbons in inclusions are prospective for search for oil and gas.

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Remarks on management and networking for the active research in the environmental field

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The united Europe and framework programmes of the European Commission (EC) give new perspectives and new demands to the individual European states and to the European researchers. The health of human beings and the environment in all its aspects are the most significant priorities.

The formation of research centres and international groups seems to be one of the best and proper ways for the realization of the integration policy in the nearest future. These groups should co-operate and apply for the EC projects as well as participate in them. The more people of the former “Eastern Europe” form networks and join their efforts, the better results will be gained.

The Centre of Excellence of the Polish Geological Institute (PGI) and its project “Research on Abiotic Environment” (REA) are shown here as an excellent example. The centre was created in the PGI, Warsaw, Poland, following the European Commission’s call in September 2001. For three and a half years it acted realizing the programme of the integration in the European Research Area in the field of abiotic environment. The project “Support for the integration of the Polish Geological Institute’s Centre of Excellence: REA in European Research Area” comprised a support for the process of integration with the European institutions. In its scientific programme, the project under description consisted of seven work packages, five of them being based on research themes realized in the Institute, i.e. problems of hydrogeology, marine geology, human-induced hazards (human impact on the environment), natural hazards (landslides and floods), climatic and environmental changes. That resulted in the mutual exchange of the knowledge obtained by scientific events of European dimension, both organized and participated in, capacity building training of scientists as well as widespread scientific information, representing the main tools for the integration in the research field.

This positive and good example and the experience gained should be followed in the nearest future due to the newest PGI project and the proposal for the FP7 call of the European Commission, aiming at effective use of the joint intellectual and technical potential. Thus it is imperative to strengthen further bi- and multilateral long-term efforts by organization of joint conferences, seminars and workshops, exchange of information and specialists, reciprocal use of laboratory facilities, advanced training of young scientists and active participation in and organization of Polish, regional and European thematic networks. The network environment–soil–groundwater will be the 2007 activity result joining the East and West European participants and co-workers.

Sustainable management and treatment of arsenic-bearing groundwater in southern Hungary

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According to Hungarian government sources, 20% of Hungarian groundwater contains arsenic in excess of EU norms, affecting water supplies to more than 400 towns and villages. The "Sustainable management and treatment of arsenic-bearing groundwater in Southern Hungary (SUMANAS)" project, funded for 50% by the LIFE Environment Programme, will develop a groundwater management plan for regions of Southern Hungary with high arsenic contents in groundwater, and will demonstrate the application of a novel arsenic removal technology and the implementation of "best practices" for groundwater use, using Békés County as the main test area. The beneficiary of the project is the Körös Valley District Environmental Protection and Water Directorate. In the project area 170 000 people are supplied with drinking water with arsenic above 10 μg/L, derived from arsenic-bearing groundwater. Locally the arsenic content of groundwater is 30 times higher than the EU norms. The need to treat As-bearing groundwater has been recognized by the EU, which has determined that water quality must be in line with EU norms by 2009.

The more specific objectives of the ongoing SUMANAS project are: 1) to assess the scale of arsenic contamination of groundwater in Southern Hungary; 2) to develop groundwater models for selected, worst affected sites; 3) to demonstrate an effective arsenic removal technology at pilot scale in selected sites in Békés County and one cross-border site in Romania, as well as removing methane, ammonia, iron and manganese where needed, with arsenic reduced to less than 3 μg/L, ammonia less than 0.3 mg/L, methane removed totally, Fe and Mn decreased below the EU norms; 4) to assess the socio-economic costs of implementing arsenic reduction technology in Hungary and evaluate its technological and economic feasibility; 5) to develop a long-term plan for sustainable management of arsenic-bearing groundwater, incorporating arsenic removal technology; 6) to disseminate the results of the project to inform stakeholders and authorities of the application of the methods and techniques in other regions of the EU.

The arsenic removal mobile pilot with a capacity of 100 m3/day continuous operation has been designed and constructed. This work was led by SELOR eeig. Presently the pilot is in operation in Gyula, Hungary. Further research and testing work will include the optimization of the use of iron-coated adsorbents for the arsenic removal, and comparison with local adsorbents: conditioned local Hungarian zeolites, perlite and adsorbing clays. A unique aspect of this new technology is the optimization of the regeneration process, whereby the lifetime of the adsorbent can be greatly extended beyond anything currently available on the market. This innovative European technology is at the cutting edge of water treatment developments for arsenic removal. Since the pilot technique allows repeated regeneration of the arsenic removal capacity of the filter material, the benefits of the pilot technology include the reduced volume of arsenic-containing wastes compared to existing technologies such as reverse-osmosis filtering or treatment using activated aluminiumosilica, (which do not allow regeneration of the filters). Recycling or other disposal (e.g. building materials) possibilities of arsenic-containing waste will also be studied during this project.

The future applicability of the arsenic removal technology depends on the critical appraisal of the results of the pilot. A performance evaluation of the treatment system will be conducted in order to determine its operational effectiveness and to verify that water effluent from the treatment system meets the maximum concentration limits, i.e. if the remediation technology is functioning as intended and if the clean-up levels and remedial action objectives are still valid. Economic viability – a cost benefit analysis taking long-term health benefits and quality of life into account – will be made to determine feasibility of technology implementation. These potential benefits resulting from the use of the pilot technology will be assessed and verified in a life-cycle-assessment (LCA), to be developed according to ISO standards.

Latvian dolomite – building stone and road construction material

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Devonian sedimentary rocks, of which **dolomite** is of particular importance, are widespread on the territory of the Republic of Latvia. The Upper Devonian dolomite of the Plavinas, Daugava and Stipinai formations, occurring at a depth of 2–10 m and forming up to 30 m thick layers, has commercial value. Approximately 80 dolomite deposits have been discovered in Latvia, with the total reserves 1500 million cubic metres. The yearly dolomite extraction is approximately 1 million cubic metres, out of which 99% is used for the production of crushed stone. Still, there is an old tradition of the use of dolomite in construction, architecture and art. Dolomite in different deposits has different colour, texture and decorative properties.

Historical use of dolomite

During the 12th–14th centuries castles and churches were built on the banks of the largest rivers, using local dolomite. Only fragments of those structures are preserved today. Much dolomite has been used in the development of the capital, Riga, from 1201 until present. The Saulkalne shelly dolomite is one of the most widely used varieties. It is an original durable dolomite type, consisting of dolomitised shells of the gastropod *Platyshisma*.

Dolomite in modern architecture

The best example is the Riga Congress Hall, decorated using pink-yellowish dolomite from the Kranciems deposit.

Prospective decorative dolomite

Dolomite, which can be used as a decorative stone, occurs in many places in Latvia. Dark grey dolomite with a particular cavernous structure was explored in the Birzhi-Puteli deposit. This dolomite is very dense and durable (pressure resistance 110–140 MPa). In North Latvia, light grey thin-layered dolomite resembling marble is found. Different types of Latvian decorative dolomite are prospective for the use in construction.

Dolomite as raw material for the production of crushed stone

A total of 2.47 million cubic metres of dolomite were extracted from the Latvian subsoil in 2006. Dolomite is the second (after the sand-gravel material) most demanded construction raw material in Latvia. In 2006, dolomite for the production of crushed stone was extracted from 13 deposits. The demand for crushed stone grows every year and new deposits are explored. Since in our country subsoil belongs to the landowners, in order to organise production, several procedures in compliance with the legal and administrative acts must be executed. In order to be able to extract dolomite, a licence for the use of subsoil must be obtained. The state executes the supervision of subsoil through such licensing.

Not all of the Latvian dolomite is suitable for the production of crushed stone. Dolomite of the Daugava

Formation is used most often. At the moment, crushed stone is predominantly produced at permanent facilities, but there is a growing tendency to use modern mobile equipment, which allows reduction of the rock transportation costs and production of higher quality crushed stone. Most of the crushed stone (~ 80%) is used in road construction. The rest is used as concrete filler.

Impacts of past mining and present aggregate quarrying on the Dalmatian karst environment, Croatia

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The carbonate (karst) terrains, which have the attributes of carbonate platforms, include the karstic Dinarides, the Adriatic belt and the Adriatic Islands. This unit covers approximately 50% of the Croatian territory. The Dalmatian karst located within the Mediterranean region lacking any significant soil cover (bare karst) due to the open hydrological system reacts very fast to anthropogenic activity. Within the karst of the Dalmatian region, more than 1000 deposits of bauxite located within a 150 km long belt were mined during the second half of the 20th century. The Dalmatian region is also an area that has a high production of primary and secondary aggregates (debris from dimension stone production). In the four Dalmatian counties aggregates and natural stone are quarried at 155 sites and there are 73 abandoned sites (Fig. 1).

Most aggregate producers in the study area are sited in counties with high population densities. Aggregate production is negligible in municipalities with low population densities, reflecting the insufficient market demand for aggregate in most of the rural areas. The bauxite production was terminated during the early 1990s due to unfavourable market prices and the expensive underground mining. The past bauxite mining practices have resulted in two types of environmental impacts: dispersion of bauxite dust by wind (more) and surface water (less), which has changed the topsoil chemistry, and numerous open pits (more than 800), some of which are deeper than 400 m. The bauxite pits are a constant threat to the water resources, since they have been used as illegal and uncontrolled waste disposal sites. The bauxites are enriched in Cr, V, As, Cd, Ni and Pb. During a geochemical topsoil mapping programme, which covered the whole of the Croatian karst region with almost 1700 sampling sites, it was determined that the soils from the Dalmatian region had 30–50% higher concentrations of these metals than other karst regions (Fig. 2). Using normalization on conservative elements, mineralogical and GIS methods, an attempt was made to determine whether the elevated concentrations of metals in soils are a consequence of bauxite mining or the bauxite signature in the soils is inherited as a geogene imprint of bauxite dust debris from outcrops on soil formation during the Pleistocene and Holocene. The carbonate aggregate quarries are visually, in landscape terms, the most dramatic anthropogenic impact on Dalmatian karst terrain. And as in the case of bauxite pits, abandoned

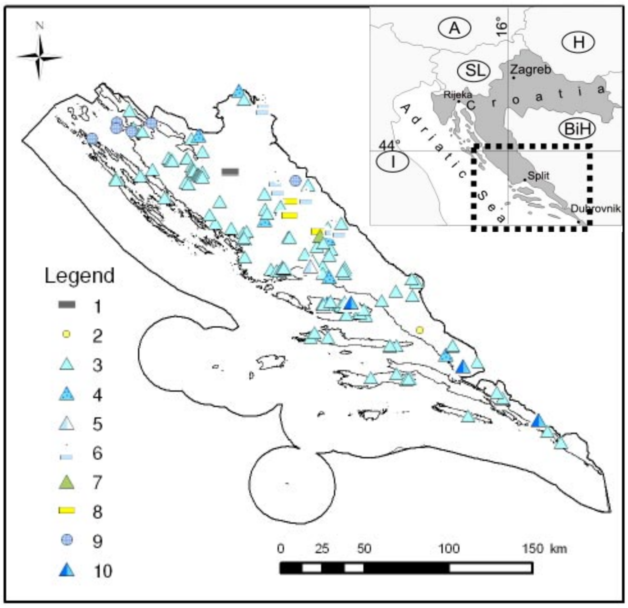

Fig. 1. Distribution of 176 active quarries in Dalmatia. 1, brown coal; 2, bituminous rocks; 3, limestone; 4, limestone breccia-conglomerates; 5, cement marls; 6, gypsum; 7, phosphorite; 8, quartzite; 9, carbonate gravels and sands; 10, carbonate rocks.

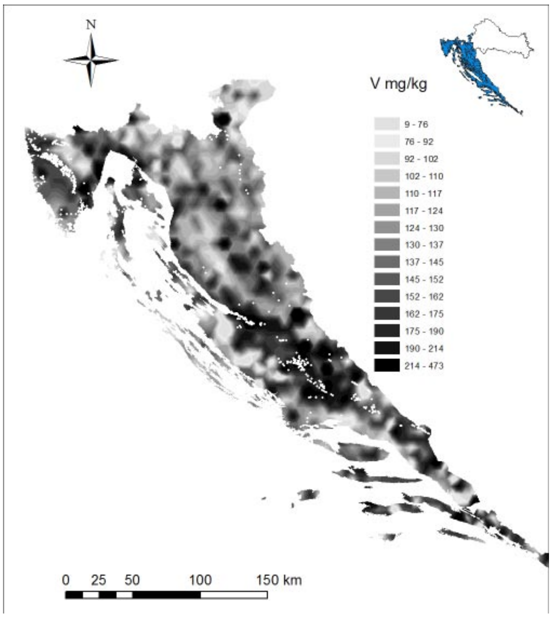

Fig. 2. Distribution of bauxite and concentrations of V in topsoil.

aggregate quarries are frequently used as illegal disposal sites threatening groundwater. In order to minimize future impacts of aggregate quarrying on the karst landscapes, GIS modelling has been proposed as a tool for the selection of optimal sites for new quarries.

The modelling is based on map-correlation and map-integration processes, in order to define relationships between spatial layers (e.g. GIS layers containing environmental variables) and combine predictor factors in supporting a hypothesis. In this study, the response variable is the set of point locations of current aggregate and natural stone quarries (termed training sites), and the predictor variables (termed evidence themes), are thematic map layers (scale 1:100 000) showing transportation network patterns, population density distribution, maps of geological mineral potential, and areas of mineral exploitation restrictions defined by Master plans of the counties (protected areas and landscapes, distance to the coast) and visual exposure based on DEM analysis. The evidence themes have categorical values (e.g. aggregate production status) or ordered values (e.g. distance to an object such as a highway). The aims of this study are to raise awareness of various mining problems and their impacts on karst, to contribute to better use of mineral resources in Dalmatia, based on the identification of more suitable areas for stone production by taking both environmental and marketplace restrictions into account and to help local environmental policy-makers to manage correctly the fragile karst environment and to preserve the natural landscape.

Contamination generated by antimony mining in Slovakia: Evaluation and strategies for remediation

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Weathering and dissolution processes in the environment of mine tailings mobilize elevated levels of toxic elements such as arsenic and antimony, which represent dangerous contaminants for the surrounding ecosystem. One of the potentially dangerous areas is the Sb deposit Pezinok-Kolarsky vrch in Slovakia. In this work we have investigated mineralogical and chemical changes taking part in the weathering of tailing minerals. We studied the chemical composition of the included minerals, oxidation rims and ochres. Considering arsenic danger, we also studied the ageing and structure of As-rich ferrihydrite. To be able to solve the problem of contaminated water, we made a few pilot experiments using Fe^0 as sorbent for As and Sb.

The ore minerals and their weathering products were studied under reflected polarized light microscope and subsequently analysed by electron microprobe

The most abundant ore mineral of tailings is pyrite. Arsenopyrite occurs also frequently. Berthierite is less common. Stibnite and gudmundite are rare.

Ore minerals are being replaced by rims in the oxidation zone. The content of As in the rims of arsenopyrite varies from 7.26 wt% to 19.06 wt%, the content of Sb reaches up to 9.46 wt%, exceeding that of primary arsenopyrite (highest content 0.05 wt%). The enrichment of the weathering rims is evident also in case of pyrite, which contains up to 5.33 wt% As and up to 7.5 wt% Sb. The same situation is characteristic of the rims on berthierite grains, where the content of As varies from 5.17 wt% to 8.61 wt%, and of Sb from 16.27 wt% to 23.73 wt%. There is nearly no stibnite in the oxidation zone of tailings, so we assume that most of the stibnite grains have already been oxidized.

The final products of sulphide weathering are Fe-ochres. The content of $(SO)_4^{2-}$ in ochres was relatively low, in most of the samples not reaching the detection limit. Four samples showed values in the range 7.43–258.25 mg/kg. The concentration of arsenic was high (0.81–51.39 g/kg), as well as that of antimony (0.33–53.97 g/kg). Fe content varied from 154.95 g/kg to 763.16 g/kg. According to neutral pH of water, ferrihydrite is the most abundant mineral of Fe-ochres. Because of the lack of long-range order, techniques other than X-ray diffraction (XRD) had to be used to describe this mineral.

Using X-ray absorption near-edge structure (XANES) spectroscopy, we determined that all probed elements (Fe, As, S) were present in their highest oxidation states. Thus, the material escaping from the impoundments is already fully oxidized, and no further changes in its oxidation state should be expected.

Extended X-ray absorption fine-structure (EXAFS) spectroscopy gave valuable evidence about the structure of As-ferrihydrite. The EXAFS spectra at the Fe K edge show that the particles in the studied material are extremely depolymerized. The octahedra $Fe(O,OH,OH_2)_6$ are connected almost exclusively by edges, forming short polyhedral chains. The EXAFS spectra at the As K edge indicate that the AsO_4 tetrahedra are attached to the iron oxide particles in a binuclear-bidentate fashion. Our results agree well with previous conclusions of Waychunas et al. (1993), obtained on a chemically similar synthetic material.

The environmental problem associated with sulphide decomposition is water contamination. To solve this problem we have to find out the proper reactive medium for the geochemical barrier. Recently we made a few batch and also column experiments using Fe for As and Sb removal from contaminated water. The water was collected from the drills in both tailings. We used laboratory Fe chip (content of Fe 99.98%, Lambda), Fe-powder (Slavus) and also some steel manufacturing by-products. All procedures were successful in As and Sb removal. The best results were reached by using laboratory iron chip in batch experiments. Very good results were obtained also during column experiments with steel manufacturing by-products.

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Multi-dimensional and multi-disciplinary approach to the regional risk management of arsenic in Pirkanmaa, Finland

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It is generally known that exposure to As or its compounds can induce a variety of adverse ecological or health effects, human genotoxicity and carcinogenicity included. Therefore, suitable measures are needed to manage risks resulting from As contamination. The regional-level risk management (RM) needs and options to control the As-related risks to human health and biota were investigated within the project "Risk Assessment and Management Procedure for Arsenic in Tampere Region" (RAMAS, http://www.gsf.fi/projects/ramas/). Several areas with an As-anomaly have been identified in Finland, the southern parts of Pirkanmaa (Tampere region) being one of these. Pirkanmaa has a long industrial history and therefore, anthropogenic As may pose additional risks. The size of the area is equivalent to half of Belgium.

At the first stage, we surveyed the available As RM measures with a focus on the national level and on the policy instruments. In addition to those measures focused specifically and explicitly on As, also instruments addressing a broader array of agents were included. Some of these instruments prioritize other elements instead of As. This introduces important questions concerning framing, coordination and trade-offs in RM. The RM measures were classified according to the target to be controlled:

- control of the sources of As emissions (source reduction), e.g., acceptance practices and quality control of products and raw materials or management of industrial and other large-scale operations;
- control of the quality of the environment (reduction of exposure), e.g., by issuing environmental quality standards or monitoring the environmental quality for As;
- control of the distribution and structure of population and natural resources (avoidance of exposure), e.g., by regional water supply and land use planning.

Most policy instruments for the RM of As have been targeted to the protection of human health. The protection of groundwater resources, too, is linked with the primary goal to protect human health. At present, the only statutory Finnish quality standard for environmental As that is based on ecological risks includes the recent guideline values for the assessment of the contamination level and remediation need of soil.

According to our study, the types of As sources are well identified in Finland, and also the reduction for most of these sources has already come through quite well. Arsenic exposure from agricultural products is now improbable, as shown, e.g., in the RAMAS study on farms. No extensive, operating industrial sources of As exist within our study area, and in general, industrial emissions have diminished largely since the 1980s. Moreover, since 2006 timber products have not been impregnated with As-containing chemicals. Solid wastes may contain significant amounts of As, but the risks appear to be under control according to, e.g., the statutory monitoring of the Pirkanmaa waste sites. However, As monitoring does not cover all possible arsenic sources. The studies on waste water generated in Pirkanmaa show low concentrations of As. The remaining anthropogenic sources of As include closed mining areas and other contaminated sites, e.g., old wood impregnation plants and landfills.

The control of As exposure through the consumption of drinking water and inhalation has been implemented at EU level by the drinking water directive (83/1998/EY) and the directive relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air (2004/107/EY), both enacted in Finland. The protection of groundwater appears to be the main objective of the EU Council Decision on acceptance of wastes on landfills (2003/33/EY). This directive has been used as a reference also for the national regulations concerning the use of secondary aggregates in earth construction and as fertilizer products. The Water Framework Directive will further extend exposure control and is anticipated to enhance it also in the case of groundwater.

Avoidance of As contamination seems the most effective RM approach. This requires knowledge of spatial distribution of As. The RAMAS studies revealed that the present environmental impacts of the anthropogenic sources in Pirkanmaa are generally quite restricted spatially, with the exception of two mine sites. In fact, it was shown that the prevailing risks to human health are associated with natural As from drilled wells used by private households and located on the high-As areas. Integrated consideration of natural and man-made As thus poses the key issue for RM, e.g., in goal-setting and focusing of efforts.

To illustrate the regional significance of the major risks identified, we produced maps to describe the coincidence of areas that have been highly valued, and the major As sources and pathways. The intersections of these potential "high-risk" areas form evident targets of RM. They include areas without organized water supply, classified groundwater areas, areas incorporated in national or EU-level nature conservation programmes, densely inhabited areas and areas to be developed for housing and tourism. Similar mapping with ArcGIS9.2 is used in the preparation of the statutory regional land use plan for Pirkanmaa, but so far without consideration of areas with high As levels. However, the occurrence of As has to a certain extent been taken into account in the plan on water services at rural areas and small villages (2001).

In practice, RM requires not only policy instruments, but also technical means and information (e.g., guidance, education, up-to-date registers). Novel technologies for the treatment of environmental media contaminated by As have not been widely applied in Finland. For example, in the case of soil remediation, excavation and disposal is the most common method to manage As-contaminated soil. Within the RAMAS project, Fe-based water treatment was tested for the cleaning of the stream water running from a mine site, but the results are not very promising. In contrast, efficient purification products and techniques for potable water are available for single households. However, interviews of Finnish suppliers revealed that these have been employed only to a limited extent. The building of a new pipeline to the nearest alternative water resource has often been the solution in the case of As problems. Such projects have also been subsidized on the basis of a specific national statute. In addition, during the first two funding periods some structural funds from the EU have been allocated to areas with an As-related groundwater problem.

Strategic management of the health risks from As in domestic water supposes the involvement of actors on all geographical levels ranging from local (municipal) and regional to national level and even beyond (e.g., in the formulation of subsidiary EU policies), and from all affected sectors. In all regional-level RM, and not only RM concerning domestic water, regional stakeholders should be involved in the assessment of As-related risks. This approach ensures that regionally valued resources are taken into account. Our studies within RAMAS will continue with additional stakeholder involvement, e.g., by organizing a seminar focused on local health authorities and regional water officers, who are among the most important actors in water supply management.

We will also analyse the management elements and their interactions behind the possible RM decisions concerning different types of arsenic contamination cases found in Pirkanmaa, such as large As anomaly areas of bedrock, a mine site (Ylöjärvi) and spatially restricted former wood treatment plants using As-containing impregnation chemical. The elements involved in decision-making could include risk assessment, regulatory instruments, technical suitability and availability, changes in land use, regional politics, available resources and social aspects.

Modelling impacts of oil shale mining on groundwater resources in the Slantsy region, Russia

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Surface and groundwater model for the Slantsy oil shale mining region near the Russian–Estonian border has been studied under the EU LIFE project “Narva Groundwater Management Plan”. In the Slantsy area, oil shale occurs as kukersite in the late Middle Ordovician and early Late Ordovician argillaceous limestones and marls, which have been mined underground since 1930.

As in the Jõhvi–Kohtla-Järve mining area in Estonia, dewatering of mines has changed the hydrological conditions and the processing of oil shale has resulted in hydrocarbon (phenol) and sulphate contamination of ground and surface waters.

There are plans to shut down the mining activities in the Slantsy region in the near future, restore the natural groundwater levels and use the aquifers as a source for drinking water supply. Termination of the dewatering pumping will have a positive effect on the water balance in the Ordovician deposits, but on the other hand, pollutants infiltrated into the subsurface during the past oil shale processing activities might be released to the environment in case the mining shafts are watered again. In addition, the aerogeophysical measurements carried out a few years ago in the cross-border area in Estonia by GTK and geoelectric soundings in the Slantsy area depict a shallow, highly conductive horizontal electric anomaly within the cone of depression of the oil shale mines. A geological explanation for the observations is the oxidation of sulphide-bearing (Upper Ordovician) deposits, which have become unsaturated due to the mine dewatering. Enriched sulphate concentrations might be released to the environment when the mining shafts in the Slantsy region are watered and the groundwater levels are allowed to recover.

Regional-scale numerical groundwater flow modelling suggests that hydrological changes and diversion of migration routes of subsurface pollution in the region can be expected after the (final) closure of mines. Such impact should be taken into account in the groundwater management plans for the Slantsy region and other oil shale mining areas approaching the end of mining activities.

Natural stone assessment with ground penetrating radar

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A study of the usability of the ground penetrating radar (GPR) in material quality assessment was carried out as a part of a larger project to characterize the properties of natural stone. The main issues were to evaluate the ability of the GPR to assess the soundness of the material, physical defects of the stone and the possible size of the extracted blocks of different rock types. Two separate case studies are presented to characterize the method. The GPR has been widely used in the investigation of rock properties, especially fracturing. Fractures represent electromagnetic discontinuities where the radar pulses are reflected from, producing an interpretable measurement profile. In particular horizontal and sub-horizontal fractures are well detected, considering they are open enough and preferably water saturated. In addition, the GPR as a technique is fast and the preliminary results can be checked immediately. It functions well with rocks, which have a low dielectric coefficient, like granite, granodiorite, etc. In this case the main interest was to compare the usability of the method in different rock types to evaluate its efficacy on a wide scale.

The material of the first case study was porphyritic granite of south-eastern Finland (Fig. 1). It belongs to the Central Finland granitoid complex and is described as postkinematic in relation to the deformation of the area. A typical feature of the rock is a strong horizontal exfoliation-type fracturing. The material of the second case study was soapstone belonging to an Archaean greenstone belt, situated in North Karelia in the border zone between the Archaean area and the Palaeoproterozoic North Karelian Schist Belt (Fig. 1). A typical feature of this material is a strong internal structure pattern with conductive minerals, which makes it more difficult to distinguish between structure and fracture.

The study methods consisted of outcrop mapping in selected quarry areas and their vicinity, complemented with a more detailed mapping and GPR measurements in the quarry areas. The GPR control unit used in this study was GSSI SIR-2000, manufactured by the Geophysical Survey Systems Inc. The GPR measurement results were processed with specific software and the results were visualized using GIS and 3D software.

With porphyritic granite, the GPR was able to detect the major horizontal and sub-horizontal fracturing. Reflections from tight fracturing, where the differences of electromagnetic properties between the rock and the fracture are not large enough, were sometimes unclear and left space for interpretation. Vertical or

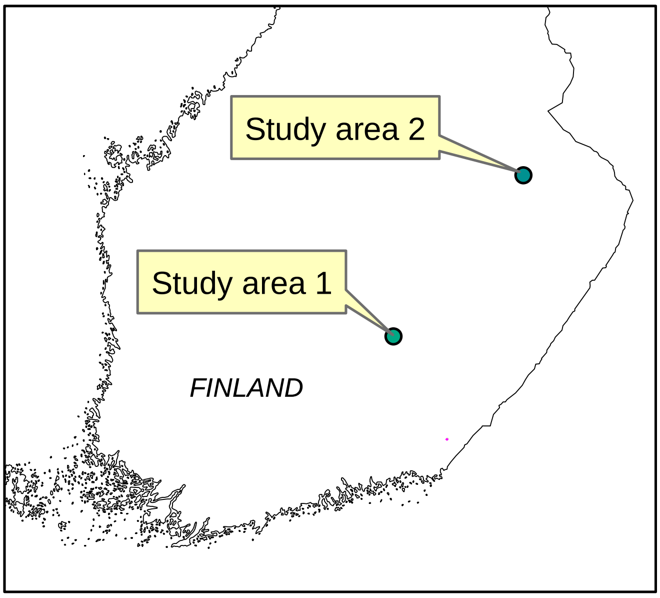

Fig. 1. Location of the study areas.

nearly vertical fractures were difficult to detect due to their small reflection surface towards the measuring antenna. The horizontal fractures near the surface were sometimes strongly weathered, providing space for surface water to collect. Those spots were detected as individual targets on the radar measurement profile.

With soapstone, the measurements revealed more of the internal structure of the rock, complicating the detection of the fracturing. Especially internal lineation was quite well visible in those sections where the stone contained more conductive minerals. Large open horizontal fractures were detectable also in this stone type, which can be helpful in planning the quarrying operations.

As a conclusion, the GPR is suitable for large-scale quality assessment of natural stone deposits and quarries. The measurements are easy and quick to perform and the preliminary results can be evaluated immediately. The development of GPS technology has also made it possible to position the measurements accurately and thus trace back the results into the quarry to help extraction planning. The differences in the measurement results of these two rock types and their interpretation indicate the importance of knowing the electromagnetic properties of the stone. Knowing the geological structure and other characteristics of the stone beforehand helps also to avoid false interpretations.

Pollution and environment degradation during the georesources recovery process, revealed using geophysical methods. Case studies in Romania

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Geoelectrical methods and their capacity regarding environment pollution research

Resistivity in the DC current method, using the vertical electrosounding technique, is most widely used in the study of environment pollution due to low costs, and real time final results. This method is based on the fact that the current penetration is commensurate with the AB emission length line, considering a homogeneous, isotropic and multistratified environment. Concerning the studies related to dams and walls of waste banks, as well as ceilings of gallery mines, the maximum investigation depth is AB/3, according to the different banking-up soil research experience of cohesive lands.

The measured parameter is the **apparent resistivity**, which depends on different petrophysical characteristics of the geological environment, geotechnical characteristics of the research area and also on the fluid content and chemism of these areas.

Beginning with the data aquisition phase with a direct geophysical problem and getting through the information processing phase with an inverse geophysical problem, the research goal is reached – final interpretation of the geological terms

During all three phases of subsoil research (aquisition, processing and interpretation), it is absolutely necessary to understand the relations between the observed geophysical information and physical properties of rocks. With the help of the new geoscience – physics of rocks, by modelling – two ways, and using both work instruments – controlled facts (field data) and refined hypothesis, a geostructural image can be found, as close as possible to the real field situation.

The spatial heterogeneities, porosity, clay content, existence of sand and gravel, density of the compaction area and ceiling fissures of gallery mines are some petrophysical elements which, when studied, either in a laboratory or in the field, become fundamental instruments for further processing and interpretation of the field data. Spatial variability cannot be observed in any level or detail using mining and drilling works. That is why geophysical tests are used, because of their capability to make an undestructive lower subspace radiogram.

The geoelectrical resistivity method has a low degree of uncertainty when certain simple measurement standards are followed:

- medium humidity of land contact;
- low relief variation of the measured land;
- availability of some control tests, parametrical by correlation with unaffected lands;
- an adequate to the land hypothesis (conceptual model).

Premises of geoelectrical measurements

All groundwater types contain dissolved solid substances and have physical, chemical and biological natural characteristics, which depend on the physical environment, and the origin and movement of water. Groundwater quality changes (especially its degradation) are caused, directly or indirectly, by natural processes or anthropogenic activities.

Prediction of the effects of human activities requires the knowledge of groundwater level, hydraulic gradient, exploitation shaft, distance of mine and mine dump (interior or exterior) to the activity area, and the adsorption capacity and hydraulic conductivity of rocks.

According to Vrba, groundwater contains many contaminants: heavy metals, organic chemicals, organic fluids, other substances (pesticides, fertilizers), bacteria and viruses. The soil pollution sources are generally related to industry.

The geochemical, hydrochemical and physical processes that influence the transport of polluting substances change the concentration of contaminants over clarke values.

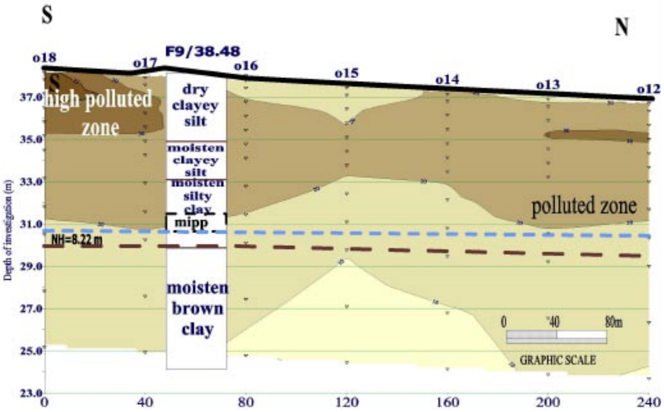

Fig. 1. Oil Terminal South typical geoelectrical section.

Legend: **o18-o12** -VES locations, ● -Oil products intensive pollution in loess, **mipp** intensive oil products smelt in borehole, **NH= 8,22** -Water table

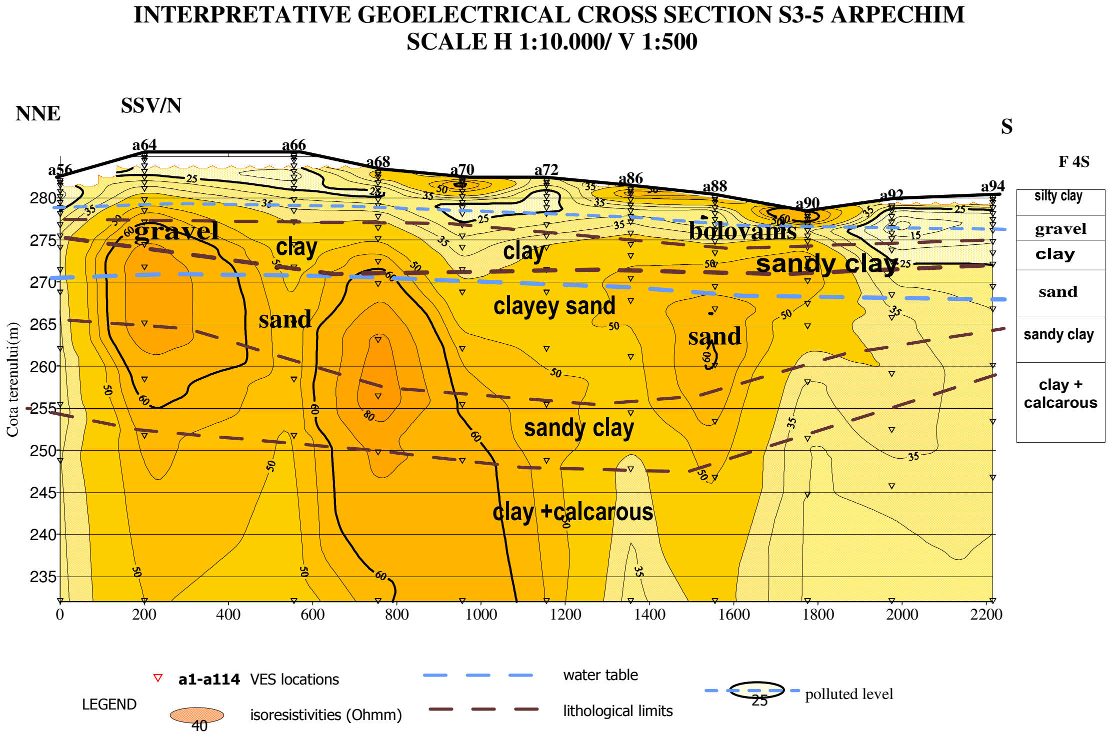

Fig. 2. Interpretative geoelectrical cross section S3-5 Arpechim.

Case studies in Romania

Soil, subsoil and groundwater contamination

The rapid geophysical methods of the study of polluted areas (especially the vertical electrical sounding method, VES) are based on the geoelectrical contrast to spatial outline the existing pollution blade into the geological environment (soil and ground waters). By means of geophysical monitoring at given time intervals, in correlation with hydrogeotechnical drilling samples, the polluted surface and the pollution blade movement direction can be outlined.

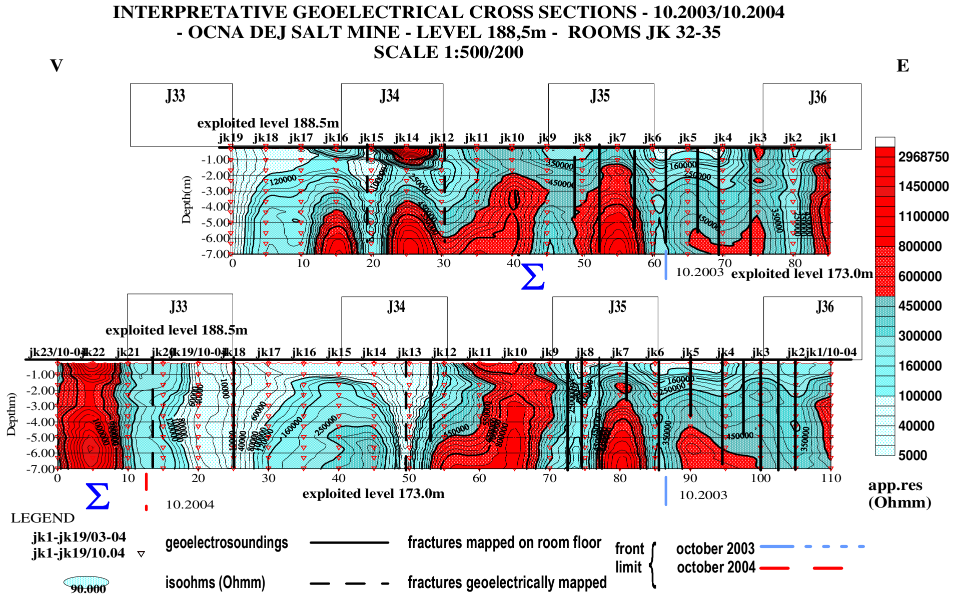

Fig. 3. Interpretative geoelectrical cross sections.

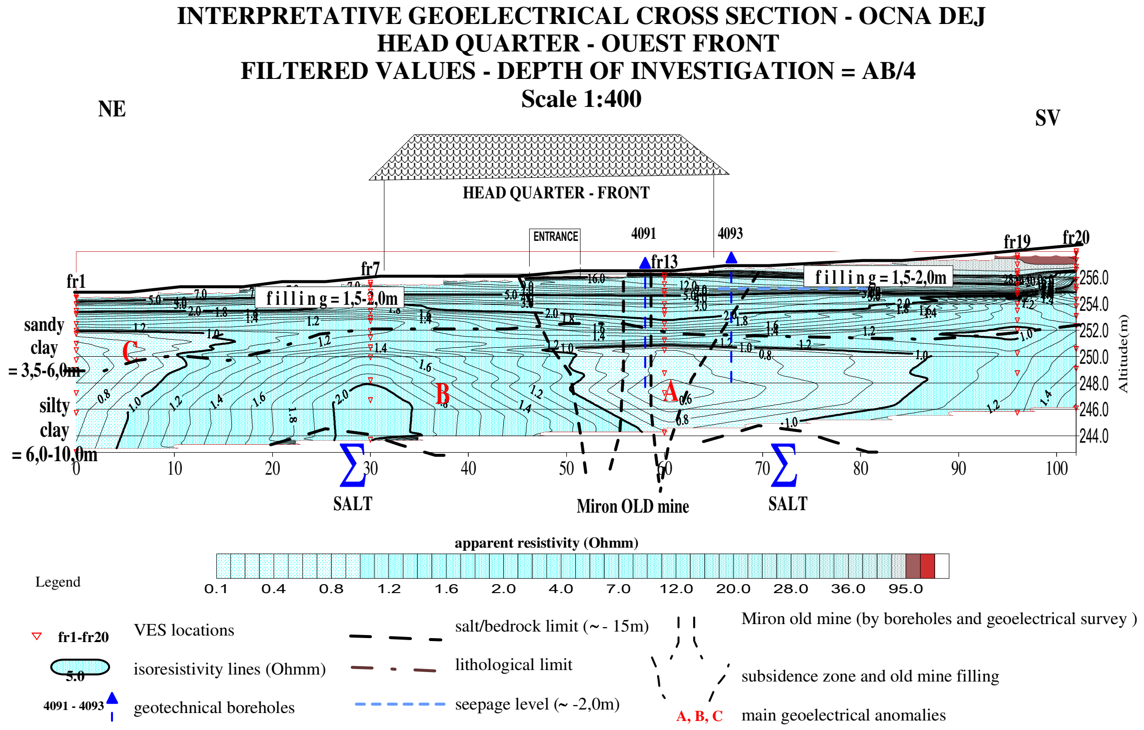

Fig. 4. Interpretative geoelectrical cross section.

Oil products pollution in old banks (**Oil Terminal–Constanta–Black Sea;** Fig. 1**):** Geoelectrical effect of fuel banks exfiltration on the loessoid water ingrained subsoil (from brow fire pipage). The anthropogenic aquifer increases the drainage of oil products.

Chemical products pollution (**Arpechim–Pitesti):** Geoelectrical effect of specific chemical substances on the aquifer near a refinery. Location of the geoelectrical minimum on the drainage directions of groundwater indicates the way by which chemical products enter the geological environment (Fig. 2).

Geoelectrical monitoring of ore exploitation

The distribution of the electric field and the resistivity (as a petrophysical parameter) are connected with the water content of rock, the fissuring systems and the geomechanical conditions. The salt of the **Ocna Dej deposit** is almost entirely represented by pure halite with more than 99% NaCl. The salt rock is compact, the structure is low-folded and the faults are rare. Connate water (fluid inclusions or trapped water) was not found in the salt deposit.

So, the geoelectrical measurements (Fig. 3) would detect fractured zones by localizing areas of high electrical conductivity. Measurements can be performed using electrode arrays in boreholes on profiles along mining rooms. The use of Schlumberger combinations of electrode arrays and profiles allows the application of tomographic modes to determine the spatial distribution of the ruptural structure. The spacing of electrodes is adjusted to suit the required resolution and the volume of the investigated rock mass.

The geoelectrical measurements provide information on the rock volume penetrated by the electric current, e.g. the locations of boundaries where the electrical properties change. The geoelectrical control of the geomechanical behaviour at the +188.5 m level floor was the final goal of our measurements to prove the existence and the continuity of the existing or induced fractures or fracture systems.

The geomechanical effect of an old mine (bubble type) upon the foundation soil of an administrative building (P+2E), **Ocna Dej Salt Mine Head Quarter:** Banking-up-soil re-lay leads to different compaction of land and to degradation of the bulding's foundation (Fig. 4).

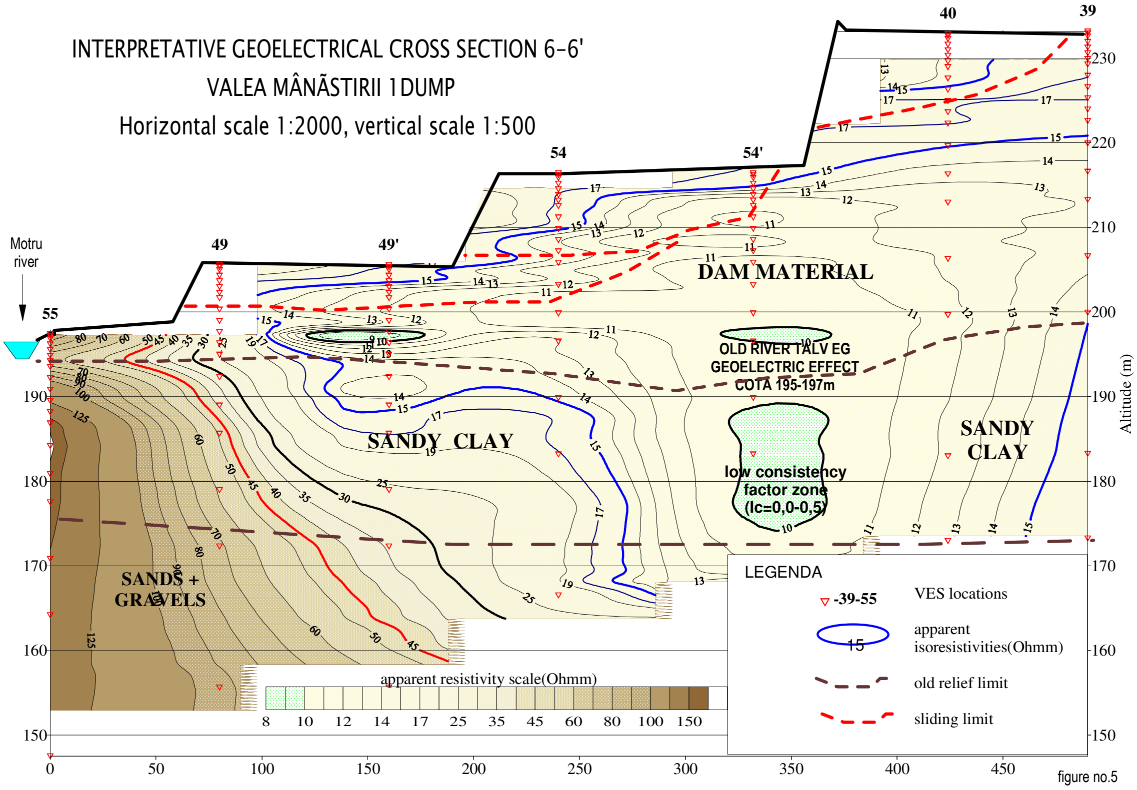

Fig. 5. Interpretative geoelectrical cross section.

Sterile and coaly material pollution, **E.M. MOTRU, Mânăstirii dump:** Dump slide in the palaeovalley of the Motru River over which sterile and coaly argillaceous material is laid. From the geoelectrical viewpoint, the coaly argillaceous material, as well as the buried mud in the old river channel by the dump, decreases the resistivity (Fig. 5).

Complete management of resources: from the discovery of solid mineral and energetic material deposits to obtaining raw materials

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Production processes of geological character

In a process of production people perform a series of activities in order to transform nature according to their requests, with a view of creating material goods and services meant to satisfy particular categories of needs. There is a series of production processes developed in or by means of intervening in the geological environment or in some mineral substances extracted from it (Marinescu 2003): processes producing services (fundamental geological research, geological prospecting; geological exploration, industrial evaluation and exploitation planning) and processes producing material goods (deposit exploitation, preparation of mineral and energetic raw substances).

The services rendered are research and planning, resulting in studies, reports and execution projects. The material goods produced can be: raw mineral substances (gases, waters, oil, coal, ores, rocks) resulting from the process of deposit exploitation, whereas the quality of mineral substances has been improved through several preparing operations (e.g. ore-concentrates) since their extraction from the deposit; different finite mineral products (raw mineral material, such as metals, coke, etc.), having a simpler composition, usually derived from the industrial processing of some mineral substances of a more complex composition (ore-concentrates, oil, coal).

Processes of production are performed in a given, specific organizational framework (universities, research and planning institutes and enterprises, enterprises producing material goods) and use quantitative factors of production (physical and intellectual work, the soil-source of mineral substances existing in deposits and quantities of substances extracted from deposits, the financial and the real capital) and qualitative ones (knowledge, qualification, data). An exceptionally important factor added to the production, the one that plans and coordinates the others, is the management.

Management of geological research processes

Geological research is performed in two distinct, very different domains of geology: the geology of the resources and technical geology. The geology of the resources deals with all aspects involved in the genesis, evolution and existence of the many energetic and non-energetic mineral resources, metalliferous and non-metalliferous, all of which are available for the humankind (Marinescu et al. 2004). In this very vast domain, one can distinguish the following processes of production: fundamental research, prospecting, exploration, industrial evaluation and exploitation planning.

Technical geology deals with the following issues: the study of the soil with a view of constructing on it (roads, railways, bridges, dwellings, aqueducts, dams, industrial enterprises, etc.) or through it (tunnels), fight against degradation (through erosion, sliding and collapse) of the soil under constructions or near them, the obtaining of natural or artificial construction materials.

The main target of **fundamental research** is raising the level of knowledge of the lithosphere in general, and of the earth crust, in particular. Its domain is vast areas, entire regions of a country and large parts of a continent, sometimes of the whole planet.

It aims mostly at as detailed as possible reconstruction of the geological evolution of a territory (dating of the phenomena and highlighting their causes), including the decoding of the processes through which the mineral and energetic substances were created. Fundamental geological research is carried out in universities and research institutes. It presupposes, besides ordinary theoretical activities, practical ones, both in laboratories (where a series of geological phenomena and processes are reproduced) and in the field (in more complex areas or the ones with specific problems, geological classification is made).

Prospecting is the geological research of vast territories with a view of discovering and summarily knowing certain accumulations of mineral and energetic substances. For the geologically less studied regions, the prospecting continues the fundamental research, being made in the areas where zones with favourable prognoses were identified and contoured. If the fundamental research was not made, its tasks are taken over by the prospecting and solved first.

Geological prospecting integrates two main stages, with different names depending on the substance or on the mineral or energetic minerals group: incipient (geological exploration, preliminary exploration, regional exploration, general exploration) and advanced (detailed prospecting, final prospecting). The incipient prospecting is conducted only if the preceding process, fundamental research, was not made. If, however, fundamental research was made, directly the advanced stage of the prospecting is undertaken.

Exploration represents a complex process of detailed research of mineral substances accumulations revealed during prospecting (advanced stage), quantitative and qualitative assessment of the content of mineral substances and determination of refinement parameters. That implies extensive research works (drilling and mining), which requires substantial investments, the largest among all geological research processes.

As well as prospecting, geological exploration is made in two stages, an incipient one (preliminary, general), and an advanced one (detailed, industrial). The incipient stage results in the preliminary determination of the contours, shapes and structures of mineral substances accumulations and qualitative and quantitative assessment of the resources potential. The advanced stage provides the necessary parameters for the industrial refinement of the studied deposit.

Industrial assessment establishes the conditions (the best options) in which the identified and defined deposits (from the geological viewpoint) can be considered industrial objects (objectives) to be used in economic circuit (extractive industry).

Management of generative processes related to intangible assets

Exploitation of deposits is a complex production process, in the course of which the raw mineral substances (solids or fluids) are extracted and brought to surface. It has three mandatory stages: deposit opening, preparing the deposit for extraction and extraction of the contained mineral and energetic substances.

The processing of the extracted raw mineral substances is the process giving mineral and energetic substances a better quality, requested by beneficiary, using some specific procedures and mechanics, which require, usually, physical processes and transformations, and less chemical processes (rarely and superficially).

Treatment represents a technique and subsequent assembly, with which ingredients are obtained from the processed mineral or energetic substances components.

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Complete management of travertine resources. Case study: Carpinis deposit (Romania)

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The possibility of travertine existence in this area was indicated, in the geological prospecting phase, by occurrences found during geological mapping. Their analysis and interpretation in the local geological context leads to some other selection, with a higher level of certainty, concerning travertine quality and quantity, in which an advanced prospecting phase was recommended (the final prospecting).

This phase presupposed a rigorous mapping (1:10 000, 1:5000), which clarified details of the geological structure and permitted elaboration of a large-scale geological map, on which, after geological cross sections were made, drilling locations were established. After the drilling, economically less prospective deposits were eliminated, and only those with high perspective were studied. After that, the approximate extension of the travertine, possibilities of quantitative and qualitative evaluation, and valorification were determined. Geophysical tests were also made, which clarified the geological structure, extension of the travertine body, and determined the thickness of the overlying rocks. For prospective bodies continuation of research was recommended, using the exploration process.

In the first phase of the exploration (generally exploration), large-scale geological maps were elaborated, geological profiles at the scales of 1:2000 and 1:1000 were compiled and very detailed mapping and geological drillings (at a short distance) were carried out. Analyses of technical samples for economical objectives followed (laboratory tests for qualitative characteristics, processing possibilities, estimation of geological reserves), which can justify the beginning of the next phase of exploration. At the end of the preliminary exploration the conclusion was that a travertine body can be considered an economic deposit and its research must be continued in a detailed exploration phase.

In the final exploration phase the deposit was thoroughly studied (highly detailed mappings, maps and geological profiles at 1:1000 or 1: 500 scale, other drillings and an experimental quarry opening) and the information obtained was used to design exploitation works and technological processing.

The travertine deposit is 800 m long, 300 m wide and aproximatelly 90 m thick, covering the old relief (Neogenous argillaceous-sandy formation) and occurring on a 1 km^2 area. At the base there is a compact travertine level (low porosity), 60 m thick, named the Banpotoc travertine, which was exploited in a quarry. This is overlain by a porous travertine level, 25–30 m thick, named the Carpinis travertine.

Being without fractures, having homogeneous physical-mechanical properties and great compactness, the travertine blocks extracted from the quarry resist vibrations and can be sliced mechanically. The recovery degree of sliced and smoothed travertine plates (from processed blocks) is 15 m^2/m^3.

Quantitative evaluation of the travertine was made as the volume of the existent resources or reserves, using the parallel vertical sections evaluation method. The obtained reserves were substantially diminished depending on the proportion of caves and caverns, sterile intercalation and weathered travertine areas. The assurance reserve degree of the quarry in which the Carpinis deposit can be exploited is over 30 years.

The surface exploitation, in a quarry, seems to be the most suitable way. The Carpinis deposit has the shape of a stratified lens, horizontal to slightly sloping, with a thickness from 35 m in the quarry area to about 90 m elsewhere. These characteristics determined the exploitation method with downward inclined slices, longitudinal cut out with the cutting machine. The value of uncover coefficient for travertine deposits, determined within the quarry area, is small: 0.56.

The wells drilled in the deposit area did not reveal any groundwater occurrence. As for any solid mineral resources, the travertine exploitation implies three compulsory phases: opening, preparation and extracting. The opening phase consists in road building and cover removal. The road was built until the bottom of the quarry and at different levels to allow access to the working areas. The average thickness of the deposit cover is around 5 m. The soft part of the cover, represented by soil and clay, is removed with a bulldozer and excavator. The hard part, represented by altered travertine, is removed by detonation. In order not to fissure the good quality travertine from below, the altered travertine is extracted with a Perrier or CTB cutting machine (Marinescu et al. 2005).

For the Carpinis deposit, the preparation phase of the downward sloping slices method, longitudinal cut out with a cutting machine, consists in lying out a flat surface on the top of the deposit (following the cover removal), in order to install the cutting machine trail. For travertine extraction, the slice is divided into longitudinal strips with Perrier and CTB cutting machines, having 2 m long arms. The strips are 20–25 m long, 1.1 m wide and 1.5 m high, and are detached from the subjacent layer by clay beds or mine holes perforation.

Blocks (2.8 m x 1.1 m x 1.5 m) are separated from the strip by natural fissure planes or by perforation and detachment with cleats. The travertine recovery as industrial blocks (35%) and useful wastes is around 48–50%.

From the Carpinis deposit the industrial blocks are transported by trucks to beneficiaries or to the processing unit in Simeria. The large-size waste material (100–500 kg/block) is stored at the quarry periphery while the rest is sent to sterile disposal. The travertine fragments smaller than industrial blocks and the wastes resulting from cutting the blocks were processed in a crusher, producing a product named agro-limestone.

The use of the travertine is determined by its aesthetic aspect and by possibilities of easy processing. Earlier it was used mainly as decorative stone, for inside and outside facing of buildings, except for the horizontal facing and areas subjected to high traffic or bad weather. From the Carpinis–Banpotoc travertine have been built (in Bucharest) Republic Palace, Telephone Palace, Mogosoaia Railway Station, Baneasa Bridge, Army Theater, Athenee Palace and Nord Hotels. The famous artist Constatin Brancusi made several sculptures of this type of travertine. Also, the travertine was used as building stone, borders, paving stones, profiled stones, mosaic slabs, various mosaic types (roman, Venice, granular), material for sculptures, chemical additive in agriculture.

The travertine has been exported to many countries: Germany, Russia, Czechoslovakia, Hungary, Poland, Lebanon, Egypt, Japan, Israel, etc. Nowadays, the main field of use is as facing material in civil and industrial engineering. The polished slabs have a look similar to worm-punched wood.

The resulting waste material is used for protection barriers (as rock fills), foundations, building works, and in agriculture (as fertilizer, agro-limestone).

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Geomanagement: the meeting of management and geology

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Two concepts or distinct sciences: management and geology

Management has a complex and comprehensive character, occurring in every domain of human activities, especially in the economic ones. Because of this, the management can be defined in many ways.

The first definition concerns the management as the science, which ensures the administration of all processes and economic or non-economic units. The other definition considers the management an important social effort of a group of people including the administration and control to achieve a certain common goal.

The third, economic definition considers the management a production factor, which organizes and coordinates the other factors (labour, land, capital) to obtain the maximum efficiency.

From the viewpoint of an enterprise, the management is a social process, which guarantees the planning, and efficient and economic regulation of its activity, to achieve a goal or a request task.

Every collectivity which wants to achieve some goals needs an action programme (depending on the earlier knowledge of management function), a certain structure (depending on the organization), harmonization of common efforts (coordination), greater involvement of its members (training) and inspection (evaluation control) to see if everything goes according to the established plan. So, it needs management.

Initially used in the Anglo-Saxon countries, the management grew and spread all over the world, today being indispensable to any organized activity. It is known as the organizing processes, captainship, which increases the efficiency of the use of material (georesources included) and human resources.

As a fundamental factor for economic growth, having the same importance as the advanced technique, the management assigns the general orientation to the progress and prosperity of society.

Geology, in a wide sense, has been considered Earth science, whereas the term was first used in 1657 by Escholt. It studies the lithosphere composition (chemical and mineralogical, petrography, lithostratigraphy, palaeontology) and architecture (local and general structure), the phenomena and processes that induce modification of lithosphere structure, and the natural general environment in which Earth develops (Lazarescu 1980).

Afterwards, as the knowledge of Earth (especially the geosphere) developed and accumulated, several sciences developed in its study, called geosciences. They appeared as a result of Earth research by independent sciences (mineralogy, petrography, geological mapping, deposits study, hydrogeology, geological prospecting and exploration, etc.) or by the proper geology intercrossing or combining with the above sciences.

The combining can be illustrated by geochemistry (combining of geology with chemistry), geophysics (with physics), palaeontology (with biology), and geomechanics (with mechanics), economic geology (with economics), environmental geology (with ecology), engineering geology (with engineering), palaeogeography (with geography), and historic geology (with archaeology), etc.

The practical goal of geology is to identify and study the mineral and energetic resources and the earth surface structure (to build different constructions, avoid land degradation, erosion, landslides and downfalls).

Geomanagement

Because it is spread in every domain of human activities, management is used also in geology. Furthermore, today we witness the birth of a new science at the intersection of geology and management, called geomanagement or managerial geology.

Geomanagement could be defined (Marinescu 2003, 2007) as the activities concerning entirely optimization of science (planning, decision-making, organizing, leading and control), aimed at proper and efficient use of all available resources (people, finances, materials, information), increasing the geological knowledge of some areas, discovery and research of mineral (inclusively for their usage as the base of a structure) and energetic resources, their industrial evaluation and exploitation and increasing their quality (processing or conditioning) to obtain the raw mineral material and finished energetic products.

The object of geomanagement is, generally speaking, the geological environment and, especially, mineral substances (or earth surface structure) included and extracted. According to this, the production processes which are evolving by means of the intervention in the geological environment or in some extracted mineral or energetic substances and by execution of some works (drillings, mining) are services-related generative processes (fundamental geological research, geological prospecting of some areas and accumulations of some mineral or energetic substances, exploration of deposits and accumulations, design of the industrial assessment and exploitation of deposits) and intangible assets-related generative processes (deposits exploitation, processing of raw mineral or energetic substances).

The given services are the research and design, and the products are the raw mineral and energetic substances, the improved quality of mineral and energetic substances (ores, concentrates, coke, etc.) and different mineral and energetic components.

Some examples of geomanagement problems are: worldwide management of mineral resources; increasing the efficiency of geological research (optimizing research methods and geological evaluation); rising the efficiency of obtaining mineral or energetic products (optimizing the exploitation of deposits, processing of raw mineral or energetic substances and treatment of mineral or energetic products to obtain final products); recovery of mineral or energetic waste; prevention, reduction and combating the environment degradation caused by obtaining mineral or energetic products (Marinescu 1997, 2007).

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Developing new projects in a mineral rich area of western Europe – recent experiences in SW England

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Devon and Cornwall are two counties located at the periphery of England that are and have been significant mineral producers. The aim of the presentation is to examine the social, economic and policy changes that have affected mineral production over the past 25 years, as well as attempting to predict how current changes will affect future production.

The key changes over the past 25 years have been in generally lower mineral prices, delineation of zones of environmental protection, tightening of environmental controls on existing producers and changes in the social licence to operate.

The sharp decreases in tin and tungsten prices in the late 1980s and 1990s resulted in the cessation of metallic mining. These decreases also exacerbated their environmental impact as closures were not wholly planned and legislated. Competition from lower cost producers has also impacted kaolin production. Construction material production has been largely consolidated into a few producers.

One of the major changes in the region has been an increase in tourism and leisure activities, notably driven by an increasing population of retirees from urban areas of England. Pressure on building land has encouraged regeneration of large areas contaminated by 19th century mining, much of which has also recently been declared a UNESCO World heritage site. These latter changes have reduced the support of local inhabitants for new extractive industries.

All these changes have produced barriers to new mining and quarrying, in particular to any greenfield operation. Possible solutions include underground extraction of building materials. However, the high environmental and permitting costs may well inhibit their development, resulting in the importation of materials from the periphery of the EU and beyond, where costs are lower.

Development of sustainable georesources for the built environment in the UK

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The character of the UK's built heritage has been largely determined by the country's diverse geology. Indigenous natural stone forms a major component of the UK's pre-1919 building stock. Stone has been used traditionally for roofing, roads, pavements, bridges, engineering works and all forms of walling. Today it is mostly employed as thin panel cladding to concrete frameworks in modern construction and is now increasingly being used in large volumes for new city streetscapes.

This presentation outlines the material requirements for the repair and maintenance of the stone-built heritage and illustrates a range of initiatives across the UK aimed at safeguarding and redeveloping indigenous resources. The importance, particularly for the repair and conservation sector, of selecting appropriate replacement stone is being recognised by architectural and conservation professionals and by local authority officials. There is also increasing recognition of the importance to the economy of the local character of the built environment in terms of its value to tourism and to architectural, historical and cultural identity (Hyslop et al. 2006).

During the mid- to late-1800s, Britain had several thousand working quarries in sandstone, limestone, igneous and metamorphic rocks, which supplied local and national requirements. Quarries ranged from those supplying material for individual buildings to the needs of cities. Many of these geomaterials were exported. In the early part of the 20th century the decline of the industry coincided with the manufacture and utilisation of other building materials, most notable concrete. In 2005 there were approximately 440 working quarries in the UK supplying exclusively building and pavement stone. In some areas, specific materials are no longer quarried. In Scotland, for example, new supplies of indigenous slate, principally for roofing, have not been available since the 1950s, and there are currently less than 20 quarries supplying sandstone, one of the most important building materials.

In Scotland, the Scottish Stone Liaison Group was launched in 2000 by the Government heritage agency Historic Scotland to identify critical resource and skills needs and to promote the sustainable redevelopment of sources of stone which were formerly available (McMillan et al. 2006). There are now examples of former quarries being re-opened to supply the growing needs of major towns and cities. Petrographic studies of masonry in buildings in the cities of Edinburgh (Hyslop 2004) and Glasgow have highlighted a range of issues including the use of inappropriate repair materials, the effects of various methods of stone cleaning and poor maintenance. Other concerns, which have been identified, include unique varieties of sandstone of local origin, not currently produced in the UK and the predicted effects of climate change on buildings. Many of these issues are now being recognised by local authorities. In addition to providing appropriate petrographic advice to a range of building professionals, the British Geological Survey is developing a GIS geodatabase of former quarry sources in order to assist decision-making for repair and maintenance, the selection of stone for both conservation and new build, and planning for the reopening of former quarries.

In Wales, the Welsh Stone Forum was formed as a result of a conference held in 2002 (Coulson 2005). Its aim is to promote understanding of the use of natural stone as a sustainable material in the Welsh environment. Public awareness and understanding of the stone built heritage is an important consideration, which could provide support for the redevelopment of important georesources in areas where the stone industry may have been dormant for many decades.

In England recent initiatives include the need to plan for the supply of indigenous stone for conservation, to source stone and to identify and quantify resources. The newly formed English Stone Forum (Doyle 2007) is enabling industry, built heritage agencies, geoconservation and nature conservation authorities to resolve conflicting interests. Government planning guidance now reflects the requirement to safeguard indigenous building stone for future use. To assist in this process, an audit of quarry sources has recently been initiated by English Heritage.

The development of locally sourced sustainable georesources for the built environment is an important consideration for the construction industry. In recent years importation of stone, produced more cheaply in less regulated environments overseas, has hindered attempts to revive the local stone and slate industries but the urgent need to meet international and government sustainability targets, for example, to reduce transport and processing energy requirements and thus reduce the related carbon footprint of the industry, has encouraged a fresh examination of the many benefits of using local resources.

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Geological heritage in Finland as an example of sustainable use of geosites

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At UNESCO's Word Heritage commission meeting at Vilnius, Lithuania, July 2006, the Kvarken Archipelago was added to the World Heritage list of protected natural sites on the basis of geological criteria. Kvarken is the first World Natural Heritage site in Finland. The Kvarken Archipelago is situated in the centre of the Fennoscandian glacioisostatic land uplift area, with an overall net uplift rate of 8 to 8.5 mm per year. At a maintained uplift rate Finland and Sweden will become connected with a land bridge across the Kvarken Strait in about 2500 years. Bothnian Bay will then become the largest freshwater lake in Europe.

Rapid land uplift gains approximately 100 hectares of new land emerging from the Baltic Sea annually at the Kvarken Archipelago, western low topography coast of Finland. The Kvarken Archipelago is characterized by extensive moraine ridge topography and a shallow brackish sea (= low salinity 0.4–0.5%). The area includes approx. 7000 islands and islets and a total shoreline of approx. 3000 km. The bedrock eroded to a peneplain already during the late Proterozoic, thus forming a unique platform for the study of rapid istostatic land uplift and its effects on geological and coastal processes as well as the biological successions of plant communities.

The Quaternary deposits on top of crystalline bedrock are composed of moraine formations, dating back to the last deglaciation. The major geomorphologic feature, which makes the Kvarken Archipelago area extraordinary, is the spectacular De Geer moraine fields deposited during the gradual deglaciation of the continental ice sheet. The De Geer moraines are exceptionally abundant, well formed and representative and frequently appear in large fields within the area. Also, hummocky moraines and other types of transversal moraine ridges occur.

At the modern sea bottom in the Kvarken Strait, where the moraines have not yet been exposed to wave and current activity, the moraines have their original form created by the inland-ice. Owing to the ongoing land uplift process these are rising above the sea surface as further invaluable geological records.

Recent developments and results of the study in the Kvarken Archipelago World Heritage project will be elucidated in the presentation. These include new excavation data of the structure of the De Geer moraines and other transversal moraines. In a later phase of the project stratotypes and morphotypes of these peculiar moraine formations will be defined. Now the county administration and environmental authorities develop facilities and a management plan for sustainable use, culture and tourism for the site.

The Kvarken Archipelago (Finland) is an extension for the High Coast (Sweden) World Heritage property, which was nominated in 2000 and is thus a transboundary serial property of both Finland and Sweden with the name High Coast/Kvarken Archipelago.

Peat production and its regulation in the Baltic States

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The industrial production of peat in the Baltic States has long traditions. The earliest information about mechanized extraction of peat dates back to the mid-19th century. The first electrical power stations fuelled by peat started operation at the turn of the last century. The production of peat briquettes started before the Second World War. In the 1960s, the expertise level of Estonian specialists allowed them to provide consultations to the Finnish state for the establishment of their peat industry. Peat fields comprise about 15–20% of the area of Estonia, Latvia and Lithuania, and the majority of these have been explored and recorded as mineral deposits. At the same time, many bogs have been taken under local and NATURA 2000 protection. The majority of large bog massifs (with areas of over 1000 hectares) are also protected.

During the last few years there has been much discussion about the use of peat resources in the Baltic States domestically, but primarily at the European level. It has been reproached that peat as a resource is not used in a sustainable manner. At the current rate of extraction, the peat in the bogs that are usable today will last for more than 750 years without any additional growth, and if we consider all the active resources (those which lack any direct restrictions related to nature or heritage protection), then for far longer than 1000 years! If we consider the expected losses, and on the other hand, the minimal growth projected today, this period is at least one-third longer. Periods of 40–50 years are generally considered when planning the use of natural resources. Therefore peat industry should be quite sustainable.

Another issue, which has been criticized in Western Europe, is that Estonia, Latvia and Lithuania pay insufficient attention to restoring bogs and reclamation of depleted production areas. The majority of the production areas in use today in the Baltic States were opened in 1960–1985. For this reason, the companies in all three countries have to follow very strict standards on how and when the damaged land must be reclaimed after production is completed.

Another important topic that has been publicly discussed is the unbalanced relationship between the extraction of weakly and well-decomposed peat. Too much weakly decomposed peat is mined in relation to its reserves and too much of it is exported. Until the disintegration of the Soviet Union, the peat mined in the Baltic States was used primarily domestically, in both agriculture and power engineering. However, after the reorganization of Soviet-style agriculture, the local need for bedding and gardening peat disappeared. Many small boiler plants were rebuilt to use imported gas; other fuels, which became more available, replaced peat briquette for household use. The question arose as to whether to liquidate this branch of industry or to find new markets. In a situation where the Baltic countries did not want its own peat, it was discovered that several EU member states and other countries needed it.

Large investments have been made in the Baltic States during the last few years to add value to peat. Modern packaging plants have been built where quality gardening soil is prepared. The entrepreneurs active today extract the maximum reserves. In addition, production areas that were abandoned in the interim have been recycled. Peat production and environmental protection are regulated by the state and supervised by the government in all three countries. The self-initiated and uncontrolled use of resources is not possible.

Natural gas industry in Iran

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Gas industry in Iran, now supplying 60 per cent of energy in fossil fuel basket, has entered the developing stage after 40 years since natural gas emerged in the energy sector. The growing demand for natural gas in the residential and industry section and supply pushing for covering this demand, are the reasons for such a statement.

In order to respond to this phase of natural gas life, Iran needs investments especially in upstream development, technology transfer and facilitating exports and imports. According to the annual report, in the long term the Middle East will be the second largest exporter region and Iran, which is the greatest holder of reserves and the greatest producer and consumer in this area, is a potential exporter for the next decades.

The Islamic Republic of Iran is able to produce more than 400 million cubic metres of natural gas per day from the giant Pars field. After satisfying the internal demand, half of this production can be exported, interregionally or worldwide. Iran was the first country in the area to export natural gas to the former USSR through an 1100 km long 42-inch pipeline. The flow was 10 BCM/Y. The pipeline to Turkey has been completed and gas flow to this country has started from 3 BCM/Y. Armenia as well will soon receive natural gas from Iran. Importing gas from Turkmenistan, Iran is an interregional gas dealer. The strategic role of the Persian Gulf and huge gas reserves in this area have provided a very good opportunity for Iran to export gas to other countries through a pipeline or in the form of LNG. In the energy sector oil products are being replaced by natural gas. That is why gas consumption has grown notably over the last decade. Transmission pipelines with a length of 20 000 km take gas from various sources to destinations in the whole country. Lines with a diameter of 56, 48 and 42 inches carry more than 500 millions cubic metres of natural gas per day.

In the 21st century liberalization of gas industry has been the main programme for the government. Treatment units, distribution and service facilities are more transferred to private investors. To overcome the high seasonal difference of consumption, installation of underground natural gas storages has been recognized as the best choice. Three underground storages are under preparation with some degree of progress to ensure natural gas supply to internal and external users.

Sustainable use of Estonian peat resources and environmental challenges

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Peatlands, occupying a total of 1 009 101 hectares, cover 22.3% and peat deposits take up 8% of the Estonian territory. Peat resources amount to 2.37 billion tonnes. Of this quantity, 1.6 billion tonnes are included in the State Register of Mineral Resources (presently a part of the Environmental Register, list of deposits). Peat is among the most important natural resources of Estonia. It is extracted from 77 deposits, and the area of production fields is 20 550 hectares. Peat production ranges from 0.9 to 1.5 million tonnes of air-dry peat (moisture content 40%) per year, depending on the weather conditions during the period of peat collection. Peat is used mainly as fuel and as substrate for growing plants in horticulture. The peat from Estonia is used both locally and is exported, mainly to be used as substrate in horticulture.

In Estonia peat is extracted in correspondence with the Sustainable Development Act, according to which the annual production must not exceed 2.6 million tonnes. The main principle of sustainable use is that the annual extracted volume must not exceed the natural annual increment.

Mires have been taken under protection on 161 575 hectares. Together with Natura 2000 areas, the protected mires occupy 211 421 hectares, whereas 72% of protected mires are raised bogs. Protection of mires is important for maintaining the ecological balance and biological diversity. Altogether 22% of Estonian mires are under protection, which is considered rather optimal.

Peat is remarkable for its ability to bind hazardous elements and therefore it can be applied in several environmental technological solutions, e.g. for wastewater treatment, as sorbent of hydrocarbons, for catching volatile toxic compounds and bioremediation of soils. Peat deposits have an ability to purify water, and wetland ecosystems are considered an important water protection alternative.

Presently a project dealing with possibilities of using peat in balneology is carried out at the Geological

Survey of Estonia. According to these investigations, approximately 1 million tonnes of peat are suitable for this purpose, i.e. it contains sufficient amounts of humic and hymatomelanic acids that stimulate life activity and is also ecologically clean, with very low contents of hazardous elements, among those S – 0.199%, Cd – 0.044 mg/kg, Th – 0.13 mg/kg and U – 0.01 mg/kg, which are several times smaller than the average contents in Estonia.

Peat production has been finished in Estonia at different times in 154 peat production areas and ca 8500 hectares are abandoned, although the peat reserves are not exhausted yet; besides, several areas are not properly recultivated. If the abandoned and non-recultivated peat production areas are not naturally vegetated, their CO_2 emission is considerable. The peat in such areas mineralises and turns unusable as mineral resource. Considering the above-said, the Ministry of the Environment has initiated the revision of abandoned peat protection areas, which has been carried out by the Geological Survey of Estonia since 2005. Presently the revision has been completed in eight counties; the work is continued in 2007 and will be completed in 2008. During the revision also the amount and quality of the remained reserves are assessed, as well as the state of water regime, drainage network and revegetation.

The results show that the state of abandoned peat production areas is variable: some are covered with forest, prevailingly with birches at former drainage ditches, later supplemented by pine trees. Grasses predominate among plants, but various species of moss occur as well. Besides, some abandoned areas are completely overgrown with cotton grass. Open abandoned peat areas, which are not covered by vegetation, are much rarer.

The above-described problem is topical in other countries as well. In 2008, XIII International Peat Congress “After Wise Use – the Future of Peatlands” will be organised by the International Peat Society in Tullamore, Ireland.

The aim of the revision of abandoned peatlands is to provide information for decision-makers whether to re-establish mire in the area, turn it into wetland, reforest it, establish a plantation of berries or a body of water.

In Estonia some plantations of cranberries and blueberries have been started in abandoned peatlands, but sometimes also projects of mire recovery have been initiated. The aim is to work out different possibilities for the recultivation of abandoned peat production areas, taking into account specific ecological and geological conditions of Estonian mires as well as the experience of other countries.

Geological aspects of risk management in oil shale mining

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Underground and surface mining in the Estonian oil shale deposit causes a large number of technical, economical, geological, ecological and juridical problems, which cannot be solved on a conventional theoretical basis. Risk management is a most powerful tool to solve the complicated mining problems. The data, which have become available in the last 40–50 years, concern the experience obtained by oil shale excavating and provide a good basis for investigations.

Risk management involves making a judgment about taking risk, and all parties must recognize the possibility of adverse consequences that might materialize. Prevention of the hazardous situations is more moral, ethical and economical than facing the adverse consequences. The risk management method gives information about the influence of different factors on mining, environment, etc. Having received the information, the management of a mine or open cast can come to adequate political and strategic decisions. The mitigation process will reduce the adverse consequences. The concept and methods of risk management may be used for different purposes and levels by investigations and exploitation of a deposit.

Investigations have shown that the share of geological data risk in mining and environmental protection is very large. It is known that the rock mass properties are variable and depend on the location. It is impossible to determine exactly all the geological features. The reliability of geological data determines the efficiency and safety of mining and environmental impact. It includes bedding, underground and surface water conditions, existence of karst, joint systems, etc.

Some of the various geological factors, relevant to Estonian oil shale mines and open casts, have been determined. For risk estimation, the judgmental and empirical approaches and event tree are used. The risk management method allows predicting the probability of a geological feature in the interested location. Getting information allows specialists to mitigate negative influence on the excavation process and environment.

Analysis showed that the risk management method used is applicable to Estonian oil shale mines and open casts, which are of particular interest for practical purposes.

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Minerals, sustainability, emerging economies, the developing world and the 'truth' behind the rhetoric

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The sustainable development paradigm was given birth in 1987 by the Brundtland report of the World Commission on the Environment and Development, which first coined the definition that sustainable development meant 'meeting the needs of the present without compromising the needs of future generations'. Who could disagree with such a high-aspirational, religious-like sentiment? But who could apply such a sentiment in real-world practical terms? Surely, non-renewable mineral resource development follows the laws of cause and effect: in simple terms extraction and usage of resources today will inevitably mean a reduction of resources tomorrow (and yet, paradoxically, it is living resources such as fish, etc. that struggle to be 'sustainable'. Sustainable development is a widely discussed but in reality little understood conceptual platform or paradigm that offers an intellectual and practical basis for mineral development with a heart and socio-environmental conscience. However, to demonstrate real-world benefits, it must be seen to be clearly applied, with tangible benefits, to real problems, real situations and real people.

There is concern that the term 'sustainable development' is being hijacked and used as a politically convenient 'sound bite' by a wide range of interest groups with disparate but self-centred agendas. Over-usage of any term across a broad range of subjects and at a relatively shallow intellectual level runs the risk of killing the creative essence of the concept itself. The sustainable development 'label' has become over-used and possibly tired and somewhat dated. Fresh thinking and new exciting applications are needed to re-energise this area. We, as responsible world citizens and geoscientists, must ensure that our specific application of the sustainable development paradigm works in a manner that leads to better practices, particularly with respect to mineral and energy resources. As part of the world geoscientific community we have a responsibility to encourage a custodianship ethos towards mineral and energy resources that: maximises resource usage and recycling; minimises waste production; is kind to the physical environment; ensures that local communities and economies receive widespread and long-lasting benefits; and deals with our responsibilities towards mineral production within our sphere of influence without unnecessarily exporting problems elsewhere.

One of the most practical beneficial applications of sustainable mineral development involves reinterpreting our legacy of geoscientific information and knowledge and setting alongside a range of other contextual datasets (national parks, city development areas, etc.) to assist with medium- and longer-term land and mineral use in a strategically planned and prioritised manner. In this way decisions can be made, backed by clear and transparent information and argument. We must also learn from past unwise mining practices and their related negative environmental, economic and social impacts. We must encourage and lobby for mining extraction best-practice for the future. One key advance is in modelling the lifecycle of minerals, mineral-bearing land and mining community-impacts from a grass-roots exploration stage to a post-mine stage. Real engagement with (including active listening!) a range of communities affected by natural resource development is fundamental. Developing customised local, national and international minerals and planning policies for the benefit of all mineral stakeholders is an aspirational outcome of our cumulative study and engagement. These approaches must acknowledge that the world has an ever-growing need for minerals, which underpins a wide range of economic benefits and should aim to move mineral development forward in a consensual, strategic manner.

The greatest danger in any application of sustainability is complacency and cynicism. This leads to outcomes such as: paying lip-service, using sustainability as a ‘gloss’ to make companies look good and improve their image and developing so-called sustainability policies that are, in reality, vacuous. Sustainability relies on a dynamic balance between economics, society, environment and politics. To a large degree economics takes care of itself as shareholders and profit drive this. Environmental concerns are, in the main, seriously attended to in most of the mining industry and this fight has largely been won (with some continuing notable exceptions). Politics is always a ‘wild card’ as it moves at the mercy of political winds and vested interests: it must be taken into account and managed but can rarely be directly controlled. The society challenge has not always been seriously addressed, is a particularly complex issue difficult and time-consuming to solve, and can be inappropriately acted upon. It is in the area of social engagement where I believe non-industry geoscientists, in particular working at universities, geological surveys and other public institutions, can make real contributions as they are seen by the general public to have fewer vested economic interests, possess bona fide expertise and act impartially. I therefore suggest it is a challenge to all of us to explain to society the need and benefits of mineral resources and the imperative of wise custodianship of these resources. The only real test of mineral sustainability is the lasting transfer of mineral-generated wealth from the mine to the people in one form or another – more sophisticated and widely accepted modelling is needed in this area to demonstrate clearly benefits and disbenefits.

Global sustainability has become even more complicated with the advent of the new economic tigers personified at the moment, such as China, India, Brazil and the like. The current climate change debate clearly crystallises the conundrums: how can a high-consuming Western world who has had it good for so long preach to an aspiring Eastern and Southern world with any real credibility? It just cannot and it is deluded if it thinks it can. China is fuelling exceptionally high raw material demand and is a key driver for the commodity super-cycle in which we find ourselves at the moment. There will be no turning back. In China and India hundreds of millions of people will attain a lifestyle that will be ever-more demanding of mineral and energy resources, and history teaches once such a lifestyle is attained, people are very reluctant to drop living standards. Geoscientists have a heavy burden of responsibility to engage with the global community and develop ever more sophisticated and customised raw material custodianship methodologies through the sustainability paradigm or something better that springs from this.

We also have a responsibility to focus on the poorest world. Europe produces a large mineral footprint and largely relies on commodities extracted from a global market. It has a responsibility to the poorest and by definition most vulnerable part of the world in particular. It is in this world where we often find examples of least-sustainable mineral development practices and the presence of the ‘resource curse’ that distorts local markets, fuels wars and creates misery. Perhaps the real test of sustainability is here: mineral development in this part of the world more than anywhere else should tangibly improve quality of life in the longer term. If it does not, it has failed the sustainability test and heads should hang in shame.

The core challenge is: can sustainable development offer a real way forward or be used merely as public relations gloss with little genuine inner-meaning? For this test to be truly successful motivation must be added to intellectual analysis, systems development and the ever-growing arrays of high-quality data our modern digital world can produce. If the motivation for mineral development is profit and profit alone, then there is little chance of new sustainability approaches succeeding.

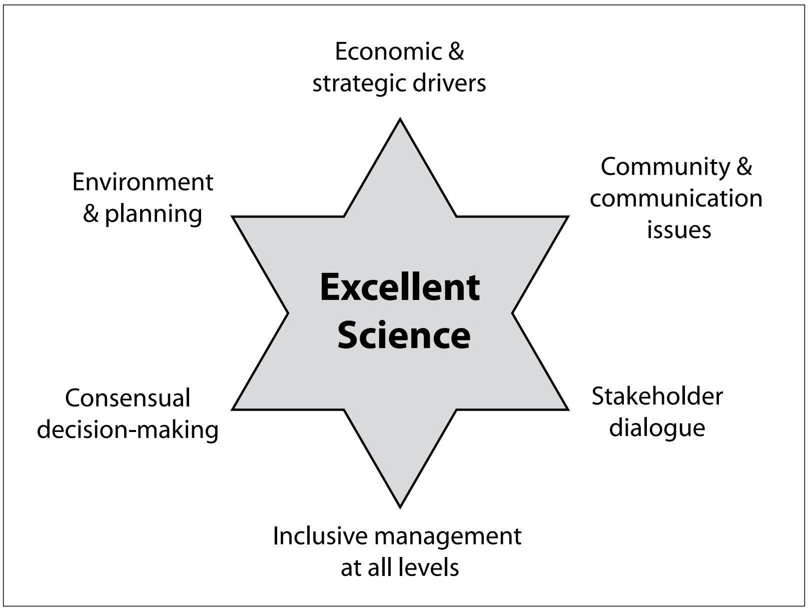

Fig. 1. Key tenets of real sustainability for the geoscientist.

The figure above summarises the key tenets of real sustainability for the geoscientist: excellent science at the heart of a dynamic process involving inclusive management and engagement, stakeholder identification, decision-making, community, economics and environment.

Origins, compositions, and technological and environmental problems of utilization of oil shales

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Oil shale (OS) is a large global resource of low-quality fossil fuel. According to the World Energy Council (WEC), the total world resources of shale oil (SO) are conservatively estimated at 3.3 trillion barrels, or around 500 billion tonnes. During 2005 and 2006, over 4.1 billion tonnes of natural oil was produced yearly worldwide. Analyses show that world oil production will start to fall sometime during this decade and will never rise again, decreasing down to about 15% in 2050. The same will happen with the natural gas resources somewhat later, and with coal – much later. In the near and farther future the other main competitors of SO recovery are tar sands that are under development and hypothetic gas hydrates of ocean floor as a challenge. The present yearly SO production is around 0.5 million tonnes.

The expansion of SO recovery, e.g. onto the 10% level of the present oil production (400 million tonnes per year) would require construction of around 133 oil retorting plants producing 3 million tonnes per year (50 000 barrels per day) each and using 5.7 billion tonnes OS altogether. For this purpose, recoverable reserves of OS with Fisher oil yield of 9%, corresponding to the expected industrial retort oil yield of 7%, in the amount of almost 150 billion tonnes (as a minimum for 25 years of operation) are required. At the usual overburden to OS volume ratio between 1 : 1 and 3 : 1, the yearly amount of rock excavation would reach some 12–25 billion tonnes or around 5–10 km^3. When mining approximately 25 m thick OS seams (around 40 tonnes shale/m^2) in open pits, the area exhausted each year would reach some 100 km^2. Yearly around 5 billion tonnes or 3 km^3 of hot treatment mineral wastes should be allocated.

The WEC estimate (2005) of commercial-grade OS suggests the organic matter (OM) content of 13–23 wt%, which in the best cases corresponds to 8.5–15% Fisher oil yield, or to 7–12% oil yield by industrial retorting, or to 6.3–10.5 MJ/kg. No commercial technologies exist for complete utilization of OS of this grade – neither for oil retorting nor for burning in electric power plants. In Estonia, SO is produced from OS with oil yield over 13–16% and electric power is obtained by direct burning of OS, yielding 8.5 MJ/kg on average.

Oil shales are either shallow marine or fresh-water and salt lake sedimentary deposits. The mineral matter (MM) content of the WEC commercial-grade OSs varies between 77 and 87 wt%. Some national lists of OS deposits include even resources with Fisher oil yield as low as 3–5 wt% or OM content around 4–7% and MM up to 93–96%. National data on WEC commercial-grade resources are randomly available.

Depending on the element composition (C, H, N, O, S) of OM, its oil yield may range from 20 to 66%. The MM composition depends on the origin of OS. According to the MM composition, the three main types of widespread marine OSs are: a) calcareous (chalk, limestone), b) siliciclastic (claystone–siltstone–sandstone mixtures) and c) mixed calcareous–siliciclastic (marls) types. The MM of the largest salt lake Green River OM has a specific composition of alternating sodium plus Ca + Mg + Fe carbonate, plus silicate. Not depending on the composition of OM and bulk composition of MM, different marine OS-bearing basins and deposits may have or may not have high contents of sulphur (S) or a large spectrum of trace (including toxic and radioactive) elements.

Uniform and specific features of OS composition cause similar and different, presently mainly unsolved problems of OS utilization under various geological, environmental and economic conditions.

Depending on the geological setting, and OS grade and composition, the problems to be solved or assessed before the industrial development are:

(1) the lower limit of energetic potential (percentage of OM and oil yield or caloric value) for the feasible OS utilization in oil retorting or in electric power plants or in their combination, and, consequently, the realistic assessment of resources and recoverable reserves;

(2) utilization and disposal of large amounts of mining and technological wastes, e.g. application of environmentally sound technologies for utilization of carbonate-rich, high-S, high trace element-bearing, silicate S and toxic element-bearing, etc. OS varieties;

(3) risks in solid waste management depending on compositional varieties of OS; e.g., somewhere in national OS overviews high contents of S, carbonates and minor elements are mentioned as an additional value of resources, however, in practice the complex use of such materials may postpone their utilization for a long time;

(4) risks of air pollution due to large-scale surface mining processes, retorting and power plants, especially having in mind the high carbonate, high-sulphur, toxic and radioactive component-bearing varieties of OS.

Depending on the physical and economic geographical setting, environmental measures for the assessment of (potential) OS mining sites should consider:

(1) global-scale factors of OS utilization according to physical geographic zonality: tropical and subtropical humid and arid zones, temperate zones, arctic zones;

(2) primary ecosystem qualities, e.g. a) species richness of terrestrial vertebrates, b) proximity to locations of sensitive species, c) surface water and riparian habitat zones;

(3) proximity to human settlements;

(4) groundwater resources: aquifers, their recharge rate and depth to groundwater;

(5) surface slope, etc.

Recently, a number of energetic and oil companies have expressed their interests in the experimental and commercial use of OS. However, during the last decades the world has got more densely populated. Understanding the responsibility for the protection of natural equilibrium in the lithosphere, hydrosphere and atmosphere has set new limits for the technological developments. Our message is that adequate developments in the R&D of the assessment of OS resources and recoverable reserves, depending on environmentally sound mining and utilization technologies, have to be achieved in using the energetic potential of OS technologies. Specific sides of settings of each OS basin, deposit and reserve and their compositions have to be considered. Presently, at the very beginning of a new era of OS developments, a simplistic manner of treatment of these developments is rather a rule than exception.

In the world OS overviews, the Estonian kukersite and *Dictyonema* shale reserves are assessed on the basis of their energetic value. In practice, the environmentally acceptable technologies exist for the kukersite OS. Large-scale utilization of the *Dictyonema* shale as well as of the Alum Shale of Sweden has so many negative sides listed among the above potential environmental restrictions and concerns that the inclusion of such resources in world OS potential is completely misleading. Actually, many OS basins and deposits are presently assessed inadequately from the positions of large-scale developments. Examples of huge development challenges with certain specific OS compositions are resources of the lacustrine Green River Basin (USA) and marine S- and trace element-bearing OS in the Cretaceous–Palaeogene basins in the Mediterranean Region.

Estonia has gained experience related to environmental problems caused by the weathering of two different types of OS wastes. Estonian *Dictyonema* shale was exposed to atmospheric conditions during open mining of phosphates, being a part of the overburden. The main negative impacts on the environment included generation of acid water as a long-term process lasting for hundreds of years, and spontaneous combustion of the open mine heaps during a couple of tens of years after mining. Estonian kukersite does not generate acid water. Its main impact on water bodies is an elevated concentration of sulphates. However, spontaneous combustion of enrichment heaps has also been observed.

The Estonian cases can be effectively used as case studies in the geoenvironmental modelling of OS utilization already during the exploration of the deposit and planning of oil shale mines. From the aspect of water pollution, the critical issue is the mineral composition of OS, as well as of the surrounding rocks. Oil shale always contains pyrite, the oxidation of which generates acid drainage. Thus, the content of acid buffering carbonate minerals, which is low in Estonian *Dictyonema* shale and high in kukersite, is the main determining factor of the water pollution. Regarding spontaneous combustion, the way in which the shale is disposed is most relevant. The disposal in high heaps with steep slopes creates the most favourable conditions for spontaneous combustion.

Oil shale burning in power plants and treating in chemical factories lead to specific sets of mineral reactions for each OS type. Still, in Ca-rich shales the processes of change are calcium dominated, so the ashes of power plants contain minerals analogous to cement clinker. The ashes harden fast under atmospheric conditions and generate alkaline water, whereas the ashes of Ca-poor shales do not harden significantly, generate dust problems and can be potentially used as filling material. Heavy metals in Ca-rich carbonate mining heaps are probably less hazardous than in Ca-poor OS, and the same stands for the residues of these different types of OS.

Geoenvironmental modelling makes it possible to predict environmental impacts of OS utilization in more detail on the basis of the characteristics of each individual OS, the surrounding rocks, and deposit type and setting, including hydrogeological conditions.

Natural attenuation of volatile organic compounds as feasible environmental remediation strategy – case study of a complex landfill leachate contaminating the groundwater system

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Spills of volatile organic compounds have a high incidence among the anthropogenic pollution, due to industrial practice, mostly in the past, and lack of proper environmental management of the generated waste. Prior to considering more complex remedial activities, it is important to assess the capacity of the natural environment to favour the natural attenuation of the spilled chemical compounds, based on the history and characteristics of the impacted site. Natural attenuation, as intrinsic degradation which reduces the concentrations of the contaminants and their metabolic intermediates or toxic breakdown products before they pose unacceptable levels of risk to human health or the environment, is a function of biodegradation rates, aquifer dispersive characteristics and groundwater flow velocity. It has been demonstrated that in many cases the natural degradation itself can act as a viable environmental clean-up mechanism. The present work describes a case study of a landfill at an unnamed site, where volatile organic compounds are leaching into the groundwater system. The purpose was to simulate in time and space the concentration evolution of selected compounds leaching from the landfill into the groundwater and to consider the possibility of relying solely on natural attenuation as a clean-up procedure at the site. Preliminarily, the overall hydrogeological conditions at the site were analysed, aiming to determine the likelihood of the leachate to spread towards areas of environmental concern. The groundwater flow system was conceptually modelled and the flow pattern was acquired by using FEFLOW 5.1, a 3D finite element code developed by WASY (WASY 2005), capable of performing numerical modelling of density-dependent fluid flow and mass transport based on the hydrogeological components included in the conceptual model. A comprehensive study of the leachate chemistry at the landfill, spanning a period of time of approximately 20 years, showed the persistence of significant concentrations of volatile organic compounds at the border of the landfill. In the next stage of the research, the presence of reducing conditions at the site was analysed, as the biological degradation of highly chlorinated solvents occurs most efficiently under strictly anaerobic conditions. Consequently, the capacity of the system to enable natural degradation was assessed. Based on the historical chemistry data and also on their polluting potential, certain compounds were selected to perform further analysis of natural degradation by analytical simulation methods. Natural biodegradation rates were developed where possible or taken from the specific literature. The natural degradation by reductive dechlorination of TCE, cis 1,2 DCE, VC was simulated, as parent to daughter products of sequential first-order decay followed by simulations of degradation of 1,1-DCA, 1,2-DCA, acetone, benzene and chloroethane natural attenuation as individual chemical compounds. Finally, the degradation pattern described by spatial-temporal evolution of concentrations was screened against specific compliance criteria at the area of concern.

Some problems of sustainable management of mineral resources in Poland

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Mining has a long tradition in Poland. In some regions it has been one of important spheres of human activity over centuries, as well as a driving wheel of industrial development of the country, particularly during the 19th century and later, after the Second World War. The mining potential is based on large mineral resources, modern equipment and services supporting mining activities, as well as higher education specialized in the field of geology and mining.

The current extraction of some minerals like hard coal, lignite, copper, lead and zinc ores, rock salt, native sulphur and numerous rock raw materials, is at a high level not only when compared to the EU countries, but also in relation to other parts of the world. The registration of data on the mineral raw material deposits and resources in Poland, as well as on the output level, is carried out by the Polish Geological Institute (Polish Geological Survey) in the frame of the System of Management and Protecting of Polish Mineral Raw Materials, named MIDAS. According to this register and a current annual report, there are more than 10 000 deposits of 51 different minerals in Poland, of which more than 6500 are mined now. In this presentation main mineral resources of Poland and a general future forecast of the mining development are briefly explained.

The future of mining development has to be considered not only from the aspect of economy and market conditions, but also with relation to intrinsically economic resources (IER) and environmental and spatial-planning conditioning. Management under the framework of sustainable development requires a change in the attitude towards ongoing activities as well as a new value hierarchy, in which, instead of direct profit, improvement of the well-being of individuals and societies comes into prominence both at present and keeping in view the needs of the future generations. This problem refers in particular to economics and rational usage of natural resources. Achievement of these tasks requires a permanent, difficult compromising between the natural expansion of man into natural environment (and the accompanying anthropopression) and protection of the environment from degradation or reduction of its important assets. In the case of mining activity, finding a compromise is especially difficult due to its very drastic interference with the environment. The core of this activity is continual taking away, i.e. permanent reduction of non renewable resources, which are constituents of the environment. Growth of environmental and spatial–planning requirements causes a drastic decrease in the accessibility of deposits, and lack of some raw materials. Some of the main reasons are development of housing and infrastructure, as well as restrictive forms of nature protection in the areas where mineral deposits are situated and documented. This concerns also reconnaissance resource areas. The accessibility of mineral deposits is currently one of the most important and unsolved problems of mineral resources management in Poland. Some of the typical examples of this conflict will be shown and explained in relation to current legal regulations.

Another group of conflicts and problems is connected with a strong impact of mining activity. Mining causes some temporary or permanent changes in terrain morphology, vegetation and landscape, and hazard to the environmental conditions is triggered due to water pollution, noise, emission etc. After relinquishing or finishing exploitation and closure of a mining plant, an excavation and mined-out area have to be reclaimed or redeveloped in order to secure the non-utilized part of a mineral resource.

Taking all mentioned problems into consideration, we can make only one conclusion – future mining has to be sustainable. This concerns all stages of mining activity, beginning from a geological study and pre-feasibility studies. This stage of mineral resources management is the domain of geology, while their management during the mining activity is mostly the task of miners and mining geologists. The third stage – management of mined-out areas – seems to be another important element in which geologists ought to participate.

Showing the scope of activities in the context of sustainable mining is one of the main topics of this presentation and discussion.

Estonian georesources in the European context

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Estonia is situated on the southern buried slope of the Baltic Shield where the sedimentary bedrock (sedimentary cover) overlies the Precambrian crystalline basement. The bedrock ranges in thickness from 100 m near the coast of the Gulf of Finland to 800 m in southern Estonia. It is composed of Vendian, Cambrian, Ordovician, Silurian and Devonian strata. The Vendian, Cambrian and Devonian complexes consist of terrigenous rocks – sands, sandstones and clays. The Ordovician and Silurian are represented by different limestones, dolostones and marls. The bedrock is covered by Quaternary sediments that have formed in the glacial and postglacial periods.

The Cambrian section contains famous “blue clay”, Lower Ordovician section – phosphate *Obolus* sandstone (shelly phosphorite), and Upper Ordovician – oil shale (kukersite). Deposits of the most important mineral resources – oil shale, phosphorite and carbonate rocks – are located in the northern and northeastern part of Estonia. Peat, sand and gravel resources are distributed almost evenly all over the country.

According to the Earth’s Crust Act of Estonia, mineral resources are clay, crystalline building stone, dolostone, gravel, lacustrine lime, lake and sea muds, limestone, oil shale, peat, phosphate rock (phosphorite) and sand. The bedding conditions and characteristics of a body for registration as mineral reserve in a mineral deposit have been established by the Ministry of the Environment. The Mineral Resource Classification System developed in Estonia (by the Estonian Commission on Mineral Resources) is based on internationally accepted principles.

Estonia is not very rich in minerals, but we have some georesources remarkable in the European context:

Oil shale. The Estonia deposit is the largest commercially exploited and best-studied oil shale deposit in the world.

Phosphorite. The Rakvere deposit (well-studied but not exploited) is the largest phosphorite deposit in Europe.

Peat. Estonia is considered as a country richest in peatlands in North Europe. The total area occupied by 9836 mires is one million hectares (about 22% of the Estonian territory). Among these mires 1626 are peat deposits of commercial interest.

Unfortunately for more than 80 years oil shale and phosphorite have been mined and industrially used in environmentally hazardous ways, devastating large regions in northern and northeastern Estonia. In 1991, considering the environmental impact and exhaustion of mineable phosphorite reserves at the Maardu deposit, phosphorite mining and enrichment of phosphorite were terminated. Phosphorite reserves were excluded from the list of mineable mineral reserves in the middle of the 1990s.

Several problems are connected with the mining and use of georesources:

Technological and technical problems

- high losses related to oil shale mining – to support the roofs of mining shafts, about 25–30% of mineable oil shale is left as pillars;
- formation of water-filled depressions on the ground (could cause collapses of oil shale mining shaft roofs).

Environmental problems

- pollution of surface and groundwater by polluted mine drainage waters;
- lowering of groundwater level and formation of large depression cones;
- changes in soil properties and overall landscape;

- formation of waste dumps (where the residual organic matter is prone to self-ignition);
- huge amounts of gaseous emissions (SO_2, NO_x, etc.) contaminating ambient air, caused by utilization of oil shale and phosphorite.

Economic problems

- the concentrates from Estonian phosphorite will not pay off;
- competition between the landusers and mining companies;
- rational use of mineral resources: as complete and complex mining as possible and the most effective utilization of explored resources (for example, peat in the overburden of oil shale; oil shale in the overburden of the phosphorite layer);
- insufficiency of natural building resources (limestone, dolostone, sand, gravel, etc.), caused mainly by different environmental and social problems of mining.

Social problems

- one part of the population is affected by mining activities;
- the greatest part of the Estonian population is against the mining at all.

The Estonian Government has decided to find a complex solution to different problems related to mining and utilization of georesources. In the future special strategies will be built and established for the use of georesources (oil shale, natural building resources and peat).

Usage of Estonian oil shale

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There are two types of oil shale in Estonia – *Dictyonema* argillite (siltstone) and kukersite. Estonian oil shale is kukersite, which is the sedimentary rock of the Kukruse Stage, the lowest Upper Ordovician stage. Kukersite deposits occur in the Estonian part of the Baltic oil shale basin comprising the Estonia deposit and the Tapa occurrence. In Russia, the Baltic basin includes the Leningrad deposit, and the Veimarn and Chudovo-Babino occurrences.

The useful component of oil shale is kerogen, the main harmful admixture is pyrite and the useless matter, i.e. ballast, is represented by lime and clay minerals. Altogether, up to fifty oil shale layers are known in northern Estonia. The lowest layers of the Kukruse Stage are of the greatest interest from the aspect of mining. The complex of layers A–F, the thickest in north-eastern Estonia, is called the mineable bed. The mineable bed forms the Estonia oil shale deposit. The northern part of the bed was broken and swept off during ice ages. That is why the layers are thickest on the outcrop. The thickness of the mineable bed in the deposit ranges from 2.5 to 3 m, run-off-mine (ROM) mass productivity per m^2 from 4.2 to 5.5 t/m^2. At the present moment the cut-off-grade is energy productivity, which should be not less than 35 GJ/m^2.

Oil shale reserves are calculated according to layers, although only layers A and D, and evidently H, consist of pure oil shale. Other layers contain smaller or larger amounts of limestone concretions with the kerogen content averaging 8%. The quality of oil shale layers varies, depending on the abundance of concretions – the more concretions, the lower the energy content of the layer.

The quality of oil shale is evaluated by considering several characteristics. The main index in Estonia and Russia is the calorific value (Q, MJ/kg), which shows the heat energy obtained at the burning of a mass unit and which correlates with kerogen content. However, oil (tar) yield (T, %) is more widely known in the world. It is defined in a laboratory in the so-called Fisher's retort, and the oil amount obtained from a mass unit in the process of low temperature carbonisation of oil shale is correlated to it. All quality characteristics are defined for dry oil shale – that is why moisture content is another important index for the quality of the product. The moisture content of commercial oil shale can be 8–14%. Working calorific value, which unites the calorific value of dry oil shale and the moisture content of commercial oil shale into one parameter, is used for calculations in sales deals. The third quality index is granulometric size (mm). The calorific value and oil yield of oil shale are proportional to kerogen content. When calculating energy productivity, one has to be aware that the calcareous components of fuel and oil raw material absorb heat in the process of decomposition, thus the actual calorific value of oil shale as ROM is lower than calculated. Dry volume weight of oil shale depends on the ratio of kerogen, lime and clay minerals, correlates to calorific value and ranges from 1.22 to 1.72 t/m^3. The volume weight of limestone, accompanying oil shale, is 2.1–2.45 t/m^3. Moisture adds weight to commercial oil shale because it fills the pores both in rock lumps and dust on the lump surfaces and between them. That is why the volume weight of moist natural oil shale is greater.

Industrial use of Estonian oil shale began during the years of World War I when fuel crisis occurred in Russia. Experimental works were started in 1916. Two mining areas – Kohtla-Järve and Ubja-Vanamõisa – emerged in three years in Virumaa county. The oil shale in Kohtla area was better and a larger oil shale industry centre formed there. In Estonia, oil shale has been extracted in over twenty mining sites – open casts and (underground) mines. At the moment six mines and open casts are in operation.

Use of geochemical data in land use planning and exploitation of georesources – experience from the RAMAS project, Finland

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Our well-being and many basic functions in the community are largely dependent on the environment and the exploitation of natural resources. It is well known that most human activities have adverse impacts on the surrounding nature unless the measures are designed and dimensioned considering the capacity of the nature. Nowadays the sustainable use of geological resources is the leading concept in responsible ventures. However, much less attention is paid to the naturally occurring geochemical anomalies in the environment. In the worst case, the anomalies pose a risk to human health, but in any case they create economic impacts. Several measures can be taken if the problem is recognized and the land use and site-specific activities are planned accordingly. A good example of such actions is the construction of a public water supply system in the areas suffering from high levels of natural arsenic. The EU LIFE-supported project RAMAS has addressed some of these questions by focusing on the risk assessment and risk management of arsenic in the Pirkanmaa region, Finland. The major natural arsenic sources in this area are certain bedrock units, till and the bedrock groundwater.

Some elements create problems which are mainly annoying, such as the common aesthetic and technical harm with iron or manganese in well water. These elements manifest their presence by strong, observable staining. Generally, the highest risks are related to elements, which are toxic in small amounts and tend to form colourless and tasteless compounds. Such substances include arsenic and some heavy metals such as nickel, mercury and uranium. All these elements form readily observable primary minerals, but when dissolved or adsorbed on soil particles, they are detectable only by chemical analysis. Most harmful components, including arsenic, can be removed from water using filtering or other physical and chemical methods. According to our studies, in the southern part of the Pirkanmaa region in more than 20% of the studied drilled wells the concentration of arsenic in water exceeds the health risk-based quality standard (10 μg/L). On the other hand, arsenic is not an issue in the public water supply systems, which exploit shallow water reserves from sand and gravel formations or surface waters.

The major part of the overburden deposited on the bedrock in Finland is composed of material that the continental ice sheet has abraded from the local bedrock. Along with the common rock-forming constituents, the potentially harmful components have been released to the geochemical and geological cycles. In the geological processes the elemental concentrations tend to decrease, but at the same time, the components are dispersed over a wider area. The transport distance and the dilution of the concentrations depend on the soil type. The source area for clay, sand and gravel is further away than for till and the fines tend to end up longer distances away from their origin. There is also internal variation in the soil profile. For example, the basal part of the till sequence is deposited closer to the source than the upper part of the till. Consequently, the overburden in glaciogenic terrains is not homogeneous, but comprises layers with contrasting mechanical and geochemical characteristics. This has important implications concerning environmental studies. Above all, the planning of geochemical sampling assumes sufficient understanding of the structure of the soil cover and scaling of sampling in accordance with the size and the foreseen use of the area. For example, sampling of topsoil is hardly sufficient if the main objective is to assess the risks owing to a construction project with major excavation operations.

The observed distribution of arsenic in soil at Pirkanmaa reflects the patterns outlined above. The highest concentrations have been found in the southern part of Pirkanmaa, within the area of arsenic-bearing bedrock units. Elevated concentrations are associated with tills, in which the highest observed natural arsenic concentrations are thousands of mg/kg, while other soil types exploited for construction materials (gravel and sand formations) or used for agricultural activities (clay and silt) seem to have low risk owing to arsenic. The lower concentrations can be attributed to arsenic-poor source areas and/or to higher geochemical dispersion during the longer transport period. Since the generic guideline value of arsenic in soil is 50 mg/kg for sensitive areas (residential areas, parks, etc.) and 100 mg/kg for less sensitive, e.g. industrial and commercial, areas, it is obvious that some natural till soils would be treated as contaminated if anthropogenic activities were involved. The main land use practise facing the potential environmental risks in such areas is related to the construction of buildings and infrastructure. Since the anomalous till areas are widely spread in southern Pirkanmaa, it is important to consider the risks in regional planning.

In general, the bedrock does not provoke any significant environmental risk of arsenic dispersion. However, the situation is different when arsenic-rich bedrock is excavated and crushed in mining areas and quarries or unintentionally during construction of road cuts or tunnels. Arsenopyrite is a relatively common accessory mineral in some rock types encountered in South Pirkanmaa. Rock horizons rich in arsenopyrite may contain arsenic up to thousands of mg/kg. Therefore, appropriate care should be taken when major excavations are carried out in the areas with high concentrations of arsenic in the bedrock.

The experience gained in the RAMAS project shows that a lot of geochemical information exists, but it is rather difficult to exploit, even in the case of a project having the resources and expertise for data acquisition. The main obstacles are 1) decentralized, variably updated and constructed databases and registers managed by different authorities, municipalities, industrial sectors and research institutes, 2) the changes in the sampling practises and analytical methods and consequently, 3) the difficulty to evaluate, combine and process the data into such a consistent form that it is reliable, coherent and feasible for a GIS-based treatment. Moreover, the use of some data is limited due to the privacy protection. According to the Commission Directive on private ownership (Directive 2003/4/EC), personal or individual data must be protected and may be published only in a form in which the identity of the property or an individual is not recognizable. In the case of RAMAS, such data includes the information on the farms, farmers, and sampling sites on private properties, e.g., private wells. This restriction prevents the import of the data into any public GIS-based database and imposes to use average values per area or some other generalized variables.

Through the years many studies with results relevant to RAMAS have been carried out, but some of the geochemical data sets produced are rather incomplete and many important parameters are missing, e.g., arsenic or many other elements have not been included in the chemical analyses or the information about the analysing method or sampling protocol is not available. For future environmental studies, at least the public bodies involved should ascertain the usefulness of their data and, e.g., review their procedures and collect as much comprehensive geochemical data as possible. Currently, the analytical methods are advanced and a large number of elements can be analysed concurrently, without any significant additional cost.

A major question is also how to distribute the information to relevant stakeholders: the authorities on different administrative levels and sectors, environmental experts working for industry and the local people. It is difficult to see any other feasible solution than the construction of a centralized database which comprises the relevant historical data from all data sources and which is updated regularly. The geochemical database should also include some supporting metadata, which links each particular data point to the geological, environmental etc. context. There are several administrative and practical problems to be solved before such an environmental information centre can be established. Quite evidently there is an increasing need for that kind of service in Finland and elsewhere.

Risk assessment of geological conditions for selective extraction of oil shale in “Estonia” mine

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With the development of new technologies and equipment it is possible to start selective extraction of oil shale. The commercial oil shale bed consists of oil shale and limestone seams of various thickness. The characteristics of oil shale and limestone seams are quite different. Usually six commercially important oil-shale seams are excavated, indexed from bottom to top by A to F. Selective extraction makes it possible to use two more layers, G and H. The rock massive often contains tectonic joints. In “Estonia” mine the oil shale bed lies at a depth of 60–70 m. The compressive strength of oil shale in “Estonia” mine is about 20–40 MPa and that of limestone approximately 40–90 MPa.

The risk assessment method determines these aspects of selective extraction which suit for geological conditions in “Estonia” mine. In Estonian underground mining the underground excavators that extract oil shale will be foremost in the modernization process. Selective extraction allows reduction of rock mass volumes during the loading, transportation and enrichment processes. Thus, about 25% of the limestone accompanying the extracting processes will be left in the mine for backfill in the excavated areas. Such a way of development will considerably reduce storing of rock waste on the ground surface and decrease harmful influence on the environment.

For selective extraction four variants with different excavation thicknesses depending on the geological conditions have been proposed. Risk analysis allows comparison of the advantages and disadvantages of full and selective extraction. Risks of oil shale losses during selective extraction are estimated using the event tree. Preliminary calculations have shown sustainability of selective extraction for the room and pillars method under the geological conditions of “Estonia” mine.

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Assessment of the environmental impact of oil shale excavation in estonian geological conditions

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Various qualities of Estonian oil shale are used in power plants to generate electricity and in shale oil processing. The mining of oil shale can disturb considerably the environment and the geological system. The different excavation methods used under certain geological conditions and accompanying development processes have various environmental impacts. Estonian mining industry takes into consideration necessary, essential details causing environmental impacts and geological disturbance.

Inventory analysis involves data collection and description of unit processes for calculation procedures. Data collection includes all emissions associated with oil shale excavation processes. Descriptive information of unit processes is a necessary tool for evaluation of operation option and environmental impact. Description of unit processes presents a general overview of mining, according to geological conditions, what technology is applied and what equipment is used in excavation processes.

The methodology of classification and characterisation of impact categories is given. The functional unit of the system under investigation is one tonne of oil shale. Mining processes cause smaller impacts on acidification, terrestrial eutrophication and ecotoxicity than the production of auxiliary materials and transportation of oil shale to customers. The other impact category includes geological disturbance, chemical composition of mine water, ground surface subsidence, recycled and deposited wastes, which were taken into consideration and discussed. This method assesses the environmental impact of excavation processes and finds a better way of conducting the proposed project. The results of the study will be used for planning new mines in accordance with environmental performances for geological conditions of the Estonian oil shale deposit.

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Options of post-mine utilization of hard coal deposits

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A number of countries abandoned mining with the upcoming substitution by readily available and cheap oil and gas. However, in recent years there are chances seen in utilizing the remaining coal resources and even the old mine workings. Several options can also provide environmentally friendly sources of energy or mitigate greenhouse gas emissions. However, some still lack the ultimate proof of technical and/or economic feasibility. The most widely used or investigated technologies involve

- Abandoned Mine Methane,
- Coalbed Methane,
- CO_2-Sequestration with Enhanced Coalbed Methane,
- Natural Gas Storage,
- Underground Coal Gasification and
- Thermal Use of Mine Water.

One commonly applied technology is the use of **methane** released in **abandoned mines** (AMM) for the production of thermal and electric energy or as a fuel in burners. Using AMM provides two major advantages: the conversion of a waste product into a clean fuel for energy production and the reduction of greenhouse gases. Most projects used degasification pipes already installed in shaft fillings for an easily accessible gas supply. Drilling production wells was required to access additional resources. Normally, AMM contains 40–80% methane. Improvement of technology allowed the utilization of gas with reduced methane contents down to 25%. Due to the Methane to Markets database only five countries (USA, United Kingdom, France, Czech Republic and Germany) run commercial projects on abandoned mine methane. Several other countries (Australia, Italy, South Africa and Ukraine) have pilot projects or are seriously considering implementation.

Coalbed methane (CBM) normally contains more than 90% methane and can substitute natural gas in most applications. Starting in 1981, the promotion of CBM as an independent source of energy by tax credits initiated the development of a CBM industry in the United States. Coalbed methane production increased rapidly within just a decade, with thousands of wells contributing considerably to the country's energy mix. Therefore, many hard coal deposits with higher methane contents became the target of exploration in various countries. The main problem remained the low permeability which made it difficult to reduce the pressure around the well to stimulate desorption. Generally, American deposits show favourable conditions for CBM production, including higher permeabilities, seam thickness, shallower depth and less structural complexity. In the meantime, countries like Australia have established a CBM industry. Today, commercial CBM production is also reported from Canada and, at a smaller scale, China and Kazakhstan. Even in Europe, new technologies like directional drilling and advanced fraccing methods initiated new exploration.

One disputed methodology is the **storage** or – as it is often called – sequestration **of** the greenhouse gas **carbon dioxide** in deep unminable coal seams or in abandoned coal mines, which, in the system of carbon capture and storage (CCS), may represent interesting options for some regions without geological alternatives. It presents a number of advantages like adsorption to the inner surface of the coal considerably reducing the risk of leakages, high theoretical capacities, claystone sealing, and correspondence of industrial point sources and coal deposits as potential CO_2 sinks.

Several R&D projects were initiated to investigate the actual potential. In Europe, the only pilot project for CO_2 storage in coal is the RECOPOL project in Poland. The low injectivity of CO_2 due to the low permeability of the coal could substantially be increased by frac stimulation. Nevertheless, the total amount injected is considered to be too low at comparably high costs. Similar projects have also been implemented in Canada, China and Japan. In fact, CO_2 storage in coal seams may be a viable option for countries with deposits with more permeable coals. From the San Juan Basin it is reported that CO_2 injection significantly improved methane recovery to 95% of the original coalbed methane in place (CO_2-ECBM). It was also concluded that injectivity was substantially reduced due to matrix swelling. It does not seem likely that CO_2 storage in deep coal seams will be a viable option in Europe in the near future.

The vast amount of coal remaining after the seizure of mining activities could provide a more easily accessible micro-porosity potential. However, due to the fracturing of roof rocks including potential claystone cap rocks, CO_2 may ultimately diffuse through the overburden into the atmosphere or towards drinking water aquifers. A current German conceptual study involves storage of CO_2 as well as the "geological filtering" of flue gas. Storage potential in coal mines seems to be limited compared to other options but may provide interesting potential in countries with growing coal production.

Storage of natural gas in abandoned coal mines could provide an alternative for conventional storage sites for the increasing storage volume required to meet peak demands. The oldest and still successfully working application is the Leyden mine near Denver, Colorado. The geological sealing is assured by the hydrostatic pressure in the aquifer underlying the coal and more than 20 m of impermeable claystone at the top. A technical challenge was the gastight sealing of four shafts. The facility can store more than the potential calculated from the cavity volume and gas compression showing the importance of adsorption. Two locations in Belgium in the Carboniferous coal deposits have considerably different geological settings but have also been operated successfully for several years. The partly flooded upper part of the Carboniferous strata and a major watertight thrust fault provided the sealing. The actual gas storage volume is the dry workings below the thrust fault. It is estimated that 8 times more CH_4 is adsorbed to coal than stored in the actual cavities. Analyses show that storing gas in abandoned mines can be a feasible alternative for conventional storage sites, particularly in conjunction with AMM or CBM production sites.

In the former Soviet Union, the technique of **Underground Coal Gasification** (UCG) was applied at an industrial scale with one project being still in operation in Uzbekistan after almost 50 years. Today, the state-of-the art technology uses two wells (vertical or directional) drilled into the coal. One well serves for the injection of oxidants and one for gas extraction. By injecting hot air or oxygen with the presence of water, a controlled partial combustion is stimulated. At high pressures and temperatures, the combustion produces town gas and other commercially valuable chemicals and water as by-products. A large number of tests have been performed at a pilot scale in the United States but also in countries like Belgium, France, Spain and New Zealand, covering a wide range of depths and seam thicknesses. A current development is the connection of UCG with CO_2 storage into the newly generated cavities.

The projects making use of abandoned mines in the **thermal use of mine water** are mostly at a small local scale. Maybe the most spectacular due to its setting is the Design School Zollverein. The 27 °C warm mine water is used as an “active insulation” rather than for actual heating. Via a heat exchanger, the water is pumped through a system of meandering tubes encased in the concrete of the walls. Most of the projects, however, work with production and injection sites, which are either drillholes or shafts. A closed circuit can be maintained: warm water is produced, thermal energy is obtained via heat pumps and cooler water is injected and heated up again along its flow path through the rocks and/or old mine workings. In a museum mine in Saxony, the heat pump is actually located within the partly flooded tin mine on the lowermost accessible level. Another project is located in the small town of Springhill in Nova Scotia, Canada. Due to the specific set-up of the coal mines, the natural convection delivered warm water almost to the surface. The Heerlen Minewater Project in the Netherlands is aimed at distributing heat from mine water to buildings in the local communities by means of a large heat pump to feed a district heat network. The set-up of the mine-water system for both areas involves drilling into the mine at different levels.

This overview shows the variety of options to use coal deposits and abandoned coal mines beyond actual coal production. Many problems have to be solved not only on a technical or economic basis but also with regard to legal regulations and acquiring public acceptance. In any case, timely consideration of the potential use during the ongoing mining activities can considerably improve technical and economic feasibility of the projects as well as the comprehensive use of available resources.

Integration of natural hazards, risk and climate change into spatial planning practices

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In search of appropriate instruments for mitigating impacts of natural hazards and climate change, as well as risks, the integration of these factors into spatial planning practices is constantly receiving more attention. Presently, the focus of most approaches lies on single hazard and climate change mitigation strategies. The current paradigm shift from mitigation to adaptation is supported by several project activities that focus on natural hazard and climate change adaptation concepts for regional development. Of great importance in the stakeholder communication process is the definition and applicability of the terms *natural hazard*, *vulnerability* and *risk*. Risk concepts are manifold and complicated and their application in spatial planning has to be analysed most carefully.

Currently, the linkages from both natural hazards and climate change to planning and decision-making are not well developed. For example, climate change adaptation and natural hazards entered European regional policy relatively recently but are rapidly growing in importance. The new Territorial Agenda of the European Union mentions hazard-related risk management as the key role in European regional development. On a European scale, projects related to natural hazards, climate change and regional development, conducted under the European Spatial Planning Observation Network (ESPON) and in cooperation with the INTERACT initiative have supported the development of risk-oriented policy recommendations (www.gtk.fi/projects/espon) and the Evidence document of the Territorial Agenda.

On regional and local scale, the Baltic Sea Region's INTERREG IIIB projects SEAREG and ASTRA used climate change scenarios to develop local climate change impact scenarios. The scenarios comprise, for example, sea-level rise and changing flood prone areas, which are analysed in interdisciplinary cooperation. The communication process developed under the SEAREG project resulted in a set of tools that bridges the gap between climate change scenarios and spatial planning by specifically addressing integrated scenario interpretation and uncertainty issues, the so-called Decision Support Frame (DSF – www.gtk.fi/slr). The DSF uses GIS applications and models, but these are only one part of the entire DSF process. The other pillars of the DSF contain a vulnerability analysis, a knowledge base and a discussion platform. The vulnerability assessment and the discussion platform particularly focus on the communication process and thus distance the DSF from pure computer-based decision-making. Both the vulnerability analysis and the discussion platform do not only help to identify the specific stakeholders to be addressed, but seek to identify and clarify climate change impacts, with the aim of taking uncertainties into account in decision-making processes. The SEAREG approach is successfully developed further by the ASTRA project (www.astra-project.org). For example, some of the cities and municipalities in the Baltic Sea Region have already taken decisions on future land use, which were directly derived from the results of the SEAREG and ASTRA projects.

Geological mapping in Latvia: from useful minerals and structures to georesources

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Traditional geological mapping in Latvia was initiated in the 1930s. Basic geological mapping, however, started just after the Second World War and thus provides a very simplified picture about geological structures and landscape-forming deposits, widespread useful minerals and some data on hydrogeology. In 1957, systematic geological mapping at a scale of 1 : 200 000 was initiated; finalizing the geological structure mapping of 25 years. In 1974, mapping started at a scale of 1 : 50 000. It was interrupted by 1992, but still covers close to 1/3 of the Latvian territory.

During the last 15 years geological mapping has been carried out in restricted local areas, mostly in relation to environmental protection or land development activities. Therefore this process is very dispersed spatially, limited in the study subject and depth (up to 10–25 m). But in the meantime traditional geological data and products have become historical data, not to be evaluated without corresponding extensive field studies. In view of this, the transformation of the geological maps to a modern geographical topographic base, application of a unified legend, translation into the local language and adaptation to GIS technologies finalizes the former stage of geological mapping in Latvia. It should be stressed that the quality of these historical data is high and they serve as the base for any geological study all over the country, but still this information is outdated.

Recent mapping activities are related to international programmes of soil geochemical cartography, studies of state-protected geological and geomorphological objects and sites and increasing studies of raw materials for building industry and construction works. The weakest point for most of the least-mentioned investigations is the quality of data, limited spatial coverage and insufficient topographic adjustment, which has resulted in falling behind with generalization of new geological data.

Contrary to topographic service and mapping, whose development has substantial motivation and support, the corresponding geological studies are very limited because the knowledge of the core subject of traditional geological mapping – useful minerals and structures – is satisfactory at least for the coming decades. This is hampering the development of detailed geological mapping, but, potentially, there are several alternatives.

In Latvia, according to the Civil Law, property rights on subsoil resources belong to the landowner. There are only some restrictions on the access and extraction of mineral resources – groundwater and hydrocarbons have been declared as resources of state importance. Besides, the state is the largest landlord of the country and municipalities operate on behalf of the state within fixed territories. However, the state as the government as well as the largest landlord, does not initiate any inventory of its own properties – georesources in a broad sense, including the mapping. Potentially, it should be recognized as one of the basic areas for geological studies in the future.

Another point of view takes into account that the value of traditional raw materials in financial terms is falling because of international trade expansion and development of globalization. This substantially reduces space for traditional geological studies that have already served society with resources for several hundred years to come. Currently most of these studies are being replaced by a broad range of environmental studies, monitoring observations, and a number of politically initiated surveys. The majority of these studies support society needs and the willingness to replace visions by data and knowledge. These are regional and physical planning exercises for medium- and long-term development. However, modern plans are not so much based on and correspondingly interested in raw materials and similar resources as a basis for development, at least in developed northern countries.

Planning and development issues include a broad knowledge of conditions, obstacles, modern and forthcoming processes in measurable units, contrary to traditional geological observations. However, there are no sufficient basic studies supporting this knowledge to serve society asking not so much for resources, minerals, and reserves as for georesources in general. This means that the role of geology changes substantially from providing services of resources to supplying the knowledge of how to support, transform or change natural conditions to satisfy the needs of society in a particular site, area or region, entitled as professional knowledge and management.

Therefore traditional geological mapping and search for useful minerals and structures can form an overall frame which should be fulfilled by a new, but not just updated, knowledge termed as georesources. This term is extraordinarily spacious and has many definitions with only a few common characteristics – spatial area, geological structure, and human knowledge. Other dimensions are still under discussion and a number of case studies are required for fundamental understanding of the core subject. In this respect historical data of detailed geological mappings can serve not only as output data but also as the subject of research, design and models for data presentation.

Geological storage of industrial CO_2 emissions in the Baltic States: problems and prospects

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Carbon dioxide (CO_2), emitted largely from the burning of fossil fuels, is the main agent causing global warming. As a result of human activities, the CO_2 amount in the atmosphere has risen significantly from 280 ppmv during pre-industrial times to 380 ppmv today and can reach 1100 ppmv by 2100 (White et al. 2003). According to the Kyoto protocol signed by the Baltic countries in 2002, the level of air-polluting greenhouse gases should be reduced by 8% compared to the 1990 level. Reduction of carbon dioxide could be reached using different measures including the improvement of energy efficiency and demand, use of renewable energy sources, and capture and geological storage of CO_2 (CCS).

Compared to the other European countries, the Baltic States are in a rather unique geological setting. Most of the countries contain a number of small basins that have different characteristics. Lithuania, Latvia and Estonia are situated within a common Baltic sedimentary basin. Therefore, a joint study is required for the assessment of the geological sinks. The source types and emission amounts differ considerably in the Baltic countries, depending on the socio-economic conditions. Geological conditions are also different, as these

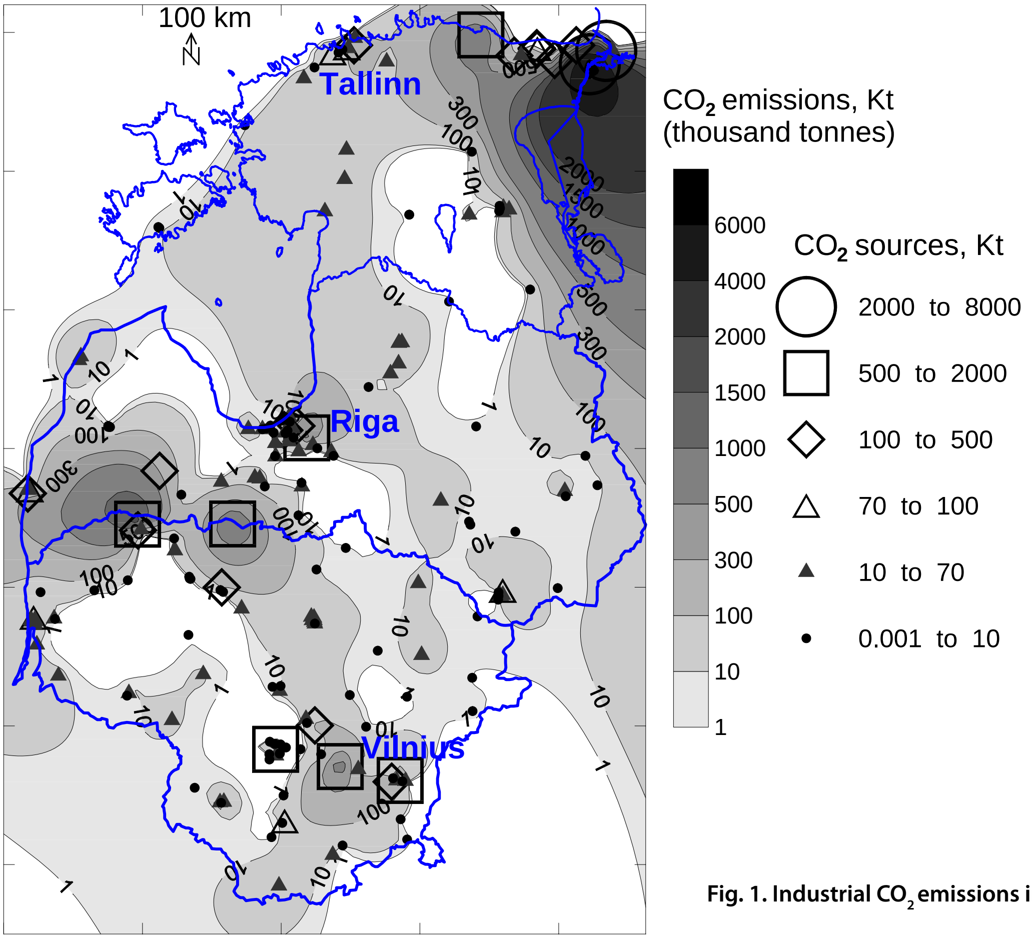

Fig. 1. Industrial CO_2 emissions in the Baltic States.

countries represent different parts of the Baltic basin.

In 2006 the Baltic States, together with other European countries, started an inventory of major CO_2 emission sources, assessment of CO_2 geological storage capacity and dissemination of information about CO_2 capture and storage in the frame of EU GEOCAPACITY and CO2NETEAST projects supported by EU Commission Framework Programme 6. Only CO_2 sources exceeding 100 000 tonnes/year (100 Kt/y) will be considered for CO_2 geological storage. Twenty-four such large sources, registered in the Baltic States in the EU Emissions Trading Scheme in 2005 (Fig. 1) produced 11.5 Mt (millions of tonnes) of CO_2 in Estonia, 5.6 Mt in Lithuania and 1.9 Mt in Latvia. All registered industrial sources produced 12.7 Mt of CO_2 in Estonia (42 sources), 6.6 Mt in Lithuania (89 sources) and 2.9 Mt in Latvia (92 sources). The energy sector is the main source of anthropogenic greenhouse gas emissions in the Baltic States, accounting for 92, 76.6 and 68% of the total CO_2 emissions in Estonia, Latvia and Lithuania, respectively.

Nine great CO_2 sources were registered in Estonia, where CO_2 emissions per capita are one of the highest in Europe. This is explained by the structure of the energy sector, using mainly Estonian oil shale for power supply. Main CO_2 sources are located in the northeast of the country, close to the oil-shale deposit. The largest CO_2 sources in the Baltic States are the Estonian and Baltic Electric Power Stations (EPSs) producing 7711 Kt and 2254 Kt of CO_2 (data of 2005). They are located close to the Estonian–Russian border and represent the largest anomaly of CO_2 emissions in the Baltic region. The second largest anomaly in Estonia is related to the enterprise Kunda Nordic Cement producing 746 Kt of CO_2 (data of 2005). A significant anomaly in Estonia occurs in the Tallinn region. In Lithuania, the most significant CO_2 emission concentration is close to the Latvian–Lithuanian border (Mazeikiai–Akmene area), where the oil-processing factory produces 1870 Kt and the EPS produces 273 Kt of CO_2. In Latvia, the main CO_2 producers are located in the western part of the country. These are the Liepaja metallurgical enterprise producing 366 Kt of CO_2, Liepaja EPS producing 108 Kt of CO_2 and the cement factory in Broceni producing 285 Kt of CO_2. Cement production is significant in northern Lithuania. The Naujoji Akmene Boiling Plant for Cement Plant produces 783 Kt of CO_2. Three EPSs emit 619, 381 and 136 Kt of CO_2 in the Riga area. This anomaly is compatible to southeastern Lithuania comprising an EPS in Elektrenai (715 Kt of CO_2), two EPSs in Vilnius (701 and 260 Kt of CO_2) and a number of smaller sources.

After capture and transport CO_2 could be stored in various underground formations, such as depleted oil and gas reservoirs, deep saline aquifers and structural traps. The Middle Cambrian siliciclastic reservoirs are considered prospective formations for CO_2 trapping in the Baltic region. The structural trapping is an option in Latvia having a number of large anticlinal structures with a total potential of more than 500 Mt in the Middle Cambrian aquifer. The shallow sedimentary basin (100–500 m), small depth of the closed oil-shale mines (60–65 m) and use of all aquifers for drinking water supply make geological conditions in Estonia unfavourable for CO_2 geological sequestration. Lithuania has a potential for CO_2 solubility storage in Devonian and Middle Cambrian saline aquifers, but without possibilities for structural trapping (Šliaupa et al. 2005).

The Inčukalns underground gas storage operating in Latvia, which is used for the supply of natural gas to Latvia, Estonia and Lithuania, is a positive example of collaboration in the region (Davis et al. 2006). The existing infrastructure of pipelines, already connecting the large Baltic CO_2 sources with Latvian prospective anticlinal structures, provides a possibility of reducing the price of the future CO_2 pipelines and a good prospect for geological storage of the substantial Baltic industrial CO_2 emissions in the most favourable geological conditions available in Latvia.

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Sustainable groundwater resource management in the Estonian oil shale deposit

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Groundwater is a water supply resource due to its usually high quality and perennial availability. However, groundwater management in the Estonian oil shale deposit often lacks sustainability, as evidenced by falling water tables and general deterioration of water quality. The mining of oil shale has the impact on groundwater quantity and quality in the Ordovician limestone aquifers.

Most underground mines are down-dip, which means that mining is generally advanced from shallow to deep levels, and below regional drainage elevations. Oil shale has thus been largely saturated by groundwater prior to mining. The deepest mine in the deposit is up to 60 m and the lowest mine 6 m deep. Oil shale is progressively dewatered to allow mining to progress, and pumping is continued to keep active mining areas dry. The groundwater management strategies focus on understanding the dynamics of groundwater and contaminants in the Estonian oil shale deposit. Specific strategies may include: collecting additional data; evaluating hydrogeology, water quality, water use, land use and population projections; determining if the water quality changes are the result of historical practices or natural causes; applying voluntary and/or regulatory control measures designed to protect the area.

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Catchment area affected by mining activities – the abandoned Smolník mine (Slovakia)

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Smolník is a historical Cu-mining area that was exploited from the 14th century to 1990. The Smolník mine was definitively closed and flooded in 1990–1994. Acid mine drainage discharging from the flooded mine (pH = 3.83, Fe = 542 mg/l, SO_4^{2-} = 3642 mg/l, Cu = 1880 µg/l, Zn = 9599 µg/l, As = 108 µg/l) acidified and contaminated the Smolník Creek water which transported pollution into the Hnilec River catchment. The Smolník mine waste area has been used as a model area to document pollution of waters, stream sediments and soils by metals and other toxic elements. Major goals of this complex study were to document creek water transport of the main pollutants (Fe, sulphates, Cu, Al, As, etc.) in the form of suspended solids, to investigate mobility of elements in common mine waste (rock and processing waste heaps and tailing impoundment) and in the soil on the basis of neutralization and leach experiments. Different methodologies and techniques for sampling and chemical and mineralogical characterization of samples were used and checked to evaluate the environmental risk of this abandoned mine area.

GIS data management structure for international co-operation projects – An example from the EU LIFE project "Narva Groundwater Management Plan"

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Proper handling and sharing of spatial data is essential for a successful co-operation in projects involving international partners. For the EU LIFE project "Narva Groundwater Management Plan" (Narva GMP) an online GIS platform was developed, which allows project partners to produce, share and visualise project data online. Scientists, researchers and policy-makers use the GIS platform for data exchange and visualisation. The service consists of two servers, one GIS data server (ERAC server) and one map server (ArcIMS server). The GIS data server contains GIS data provided by all partners. The ArcIMS server enables visualisation of the data through a map interface.

The GIS data server is part of the open source ERAC network. All partners access the information by logging into the system. After username and password verification the user is able to download data for the desktop application. Since active data sharing could lead to an unstructured storage system, uploading or modification of existing data is not possible for the user (read-only) but uploading has to be done by the webmaster (GTK). Partners who are providing new data sets are asked to fill out the metadata system (MIS), however, this meta information will not be accessible for the user.

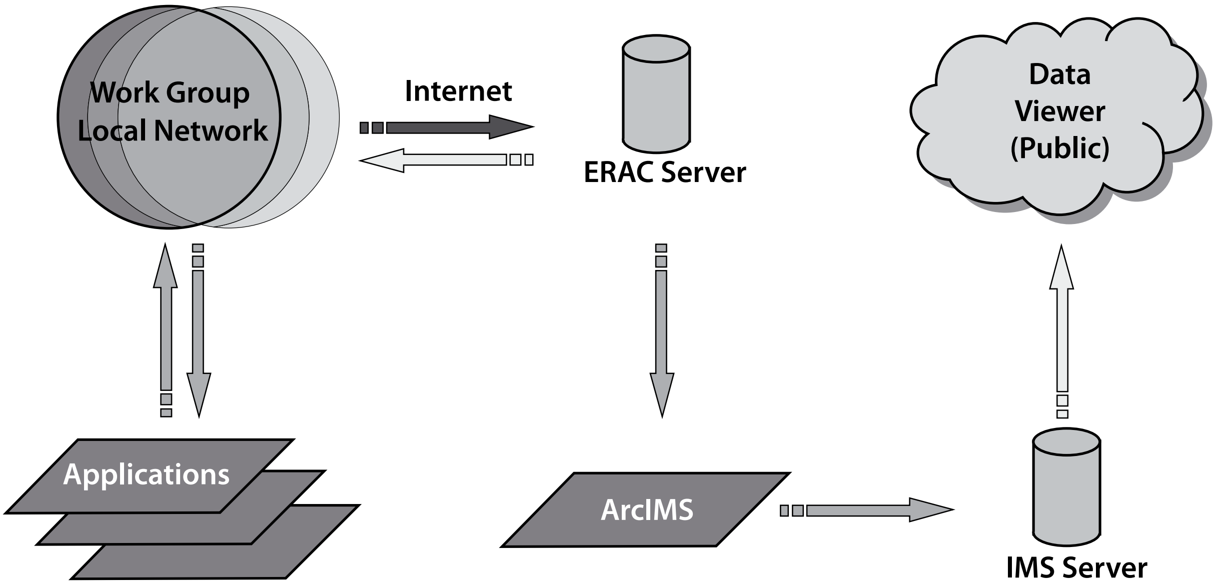

Fig. 1. Structure of data handling in the Narva GMP project.

The main function of the ArcIMS GIS image server is to visualise geographical information. It is a selective copy of the ERAC server based on the information provided by the metadata system. The data of the public ArcIMS is not downloadable. The combination with the ERAC server makes a data-driven GIS with a focus on information sharing.

In the Narva GMP information is collected from various sources and made available for visualisation with ERSI software products. The public ArcIMS server (http://geomaps.gtk.fi/website/NarvaGMP2IMS/) holds all information for the Narva GMP in the service NarvaGMP2IMS. This service can be loaded to the Windows Internet Explorer by double-clicking on the link on the web page. By doing so the ArcIMS viewer is loaded and project data can be visualised by project partners or the interested public.

The importance of the mineral raw materials supply in respect to the competitiveness of the European economy

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After decades of low commodity prices, a new bull market for commodities began in 2003 which pushed up commodity prices in 2007 to levels which have not been seen for years. This is obviously not attributed to a specific shortage of a single commodity, but to a complete structural change. With the addition of highly populated, developing and transforming countries, such as China, Brazil and India, over half of the world's population are now also involved in the worldwide raw materials market.

EU industry is in general highly dependent on imports of raw materials. Reliable and steady supplies of raw materials at competitive prices are vital for the EU industry and citizens. Some raw materials of vital importance to the downstream industry and thus for the EU's competitiveness are available in only few countries. Moreover, they are partly extracted by only a small number of multinational mining companies. At least for some materials a shortage in supply combined with a high demand could pose a risk to the security of the EU raw materials supply. Forecasts predict no early change of this situation.

Metallic raw materials are indispensable parts of industrial production and therefore of strategic importance for the external competitiveness of the European Union. Among others, the aerospace, electronic and automobile industries are especially dependent on metallic raw materials. Many important metal ore deposits are concentrated in only few countries. For instance, about half to two thirds of the worldwide production of Aluminium (Bauxite), Lead, Copper, Nickel, Zinc or Tin is produced in only thee countries. Mining production of metals is likely concentrated on only a small number of companies, although this concentration is slightly down on 2003. The bulk of extraction is accomplished by multinational companies from the U.S.A., Canada, Australia and Chile. Between 2003 and 2007 global extraction of metallic raw materials has increased further. Worldwide demand as well as European demand for metallic raw materials has likewise grown further between 2003 and 2007. EU demand amounted to a quarter up to a third of worldwide demand. EU import dependency on metallic raw materials can be regarded as rather high since between 74 % and 86 % of the raw materials such as Aluminium (Bauxite), Lead, Copper, Nickel, Zinc, Tin etc. have to be imported.

Czech Geological Survey – Geofond: profile of the organization

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Czech Geological Survey – Geofond has a status of a state organizational body established by the Ministry of the Environment. Its main purpose is the administration of state geological service at the territory of the Czech Republic.

In 1952 was established so called „Geological fund“ from archive of research reports, expert opinions, documentation and geological maps. In 1975 was established a separate budget organization „Geofond“, in 2002 was the name of the organization changed to „Česká geologická služba – Geofond = Czech Geological Survey – Geofond“. There are three main activities of this organization:

State geological service

Registration of geological works
- review of geological projects and the organizations that undertake them

Mineral resources
- protection and utilization of mineral resources
- providing a register of the mineral deposits and reserves
- documents for state mineral policy and the utilization of national mineral resources

Impacts of abandoned mine workings
- registration of mine workings and their impacts
- assesment of reported impacts of mine workings

Urban planning
- data processing of specific geological conditions
- reports on documentation related to development and land-use planning
- information on the geological features, which may affect of land-use planning
- edition of thematic maps of
    - protected mineral deposits
    - abandoned mine lands
    - landslide areas

Public access to all basic information about these features is allowed through the Web applications. The systems are based on the ArcIMS technology of ESRI, applications are continuously updated and there are free of charge.

Archive

It contains unpublished geological documentation, maps and material documentation.

- geological reports about the geological works are collected since 1862, about 113000 items.
- unpublished mineral reserves reports are collected since 1952, about 3600 items.
- geological foreign travel reports are collected since 1920, about 10500 items.
- old borehole reports, about 72500 items.
- geological maps at scale 1 : 2 800 to 1 : 200 000, app. 13 thousands.
- soil fertility maps at scale 1 : 5 000, app. 16 thousands.
- historical mining maps various scales, app. 9 thousands.
- thematic maps at scales 1 : 25 000 and 1 : 50 000, app. 3.500 thousands.
- borehole cores (or its parts), app. 1 550 boreholes
- micropaleontological samples, app. 10 000 samples.

Information about all these archived documentation is also available through the database application „Automated System of Geological Information“ within the CGS-Geofond website. It contains now about 203500 items.

Information system

Geoinformation system of ČGS-Geofond is a very high specialised related database system, continuously updated and developed. It contains three main subsystems:

- Archivne Documents subsystem includes data about reports on the results of geological works and statistical statements and other related documents.
- Graphic Document subsystem contains digital reports on the results of geological works and other documents stored at CGS-Geofond.
- Factual subsystem is a collection of databases, containing information about geologically documented objects or phenomena with the location (JTSK-system).

Which metals and minerals will be our future resources?

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Who needs mineral resources?

Many modern and urbanized persons, often holding influential positions in economy, politics and culture, are surprisingly unaware of their own needs and consumption patterns of mineral resources. Instead, they often consider exploitation of mineral and energy resources unnecessary. The same people may even consider mining as something that belongs to the past and a threat to the local environment and future development of human cultures. What these people *ought to* know is that the advanced cultures have required, and will continue to require, the exploitation of mineral resources.

This can be exemplified by some simple statistics on the current patterns for high-intensity consumption countries (EU, North America, Japan and Australia), where an average person annually consumes 4 tonnes of petroleum, 4 tonnes of coal and 4 tonnes of sand/gravel, while the per capita need of metals is 500 kg iron/steel, 25 kg alumina, 10 kg copper and 50 g of uranium. These figures reach astronomical magnitudes if they are multiplied by 950 million, which is the population in those countries. The significance of the above-mentioned per capita figures is further emphasized when low-intensity consumption patterns in less developed countries are replaced by high-intensity patterns as it now happens in China with its 1.3 billion inhabitants.

A wide range of mineral resources are currently exploited globally with good profit due to the current exceptional metal and energy prices. A common discussion topic among experts in resource economy and resource politics is whether we will soon go back to “normal” metal and energy price levels or whether the present mining boom will continue. It is easy to find arguments supporting a continued high demand for many types of mineral and energy resources as long as:

- the consumption patterns in the developed countries remain unchanged;
- new technological products, with “new” metals, will appear on the market;
- the economy in China will continue to expand;
- the political situation in Iraq remains unsolved.

What mineral and energy commodities will we need in the future?

It is always difficult to predict which mineral commodities future generations will need, because it depends on the industrial products that will be required on the future markets. These markets will in turn reflect the technological innovations as well as political and economic climate that will be faced in the future. In any case, if we have a look at the present consumption patterns, we see the following trends:

Classical metals

Some metals, e.g. Fe, Cu, Au and Ag, have been used by human cultures for several millenia. In spite of this long exploitation history, there is still in 2007 a very strong demand for each of these metals.

“20th-century” metals

Ni, Zn, Mo, Pb and Al came on the market as a result of the development of specialized industry products during the 20th century. In spite of recent discoveries of large nickel resources, there is no sign of lower prices for nickel or for the other metals of this group.

Post-modern metals

Pt and Pd have had a dramatic price rise during the last ten years, mainly related to environmental regulations in the car industry. Current prices are comparable to, or even higher than, that of gold.

Future metals

In, Ta, Ga, Ge and Te have come into fashion quite recently. It is generally considered that they will play an increasing role in technological innovations and thus also in exploration. As many of these metals are so new on the market, very little is yet known about appropriate reserves and very small quantities of these metals are recycled. This is particularly true for indium, but all these metals are currently considered as future metals.

Industry minerals and construction materials

This group comprises a variety of mineral resources, which have had an expanding market for several decades. Quartz for fibre optics and solar cells, olivine for the iron metallurgy industry, ilmenite for the paint industry, limestone for numerous purposes and refined dimension stone products are examples that probably only describe the beginning of a relatively new field in economic geology.

Energy resources

Oil, gas and uranium are wheel hubs for most of the industrial processes and transports as well as the main energy source for private use. Dramatic political conflicts in the most important oil-producing region of the world have shown how desperately we need these products, which have resulted in the highest energy prices ever.

Water

The access to clean water is a basic need for all biological organisms but it is too often forgotten by human cultures. If we waste or overuse our aquifers, water may become as precious as oil or gold.

Where can we find these resources?

The above-mentioned summary has demonstrated a high current (and most probably also future) demand for a number of mineral and energy resources. But will Mother Earth have enough supply to cover all these needs? Many densely populated regions in Europe and Japan will have problems to find domestic resources, while this problem is not so critical in North America, Australia and the Fennoscandian region (and associated offshore regions), which possess potential resources for all these commodities. Mineral resource exploitation in less developed countries offers many options but is also coupled to many ethical questions.

How can we find these resources?

The most obvious mineral resources have probably already been found. Future discoveries of mineral deposits and hydrocarbon resources will therefore rely on increased skill in resource geology and access to new methods. The only way to meet such a challenge is to:

(1) continue educating future generations of geoscientists who must receive a broad and deep understanding of rock-forming and ore-forming processes as well as knowledge on how hydrocarbon and groundwater resources form and

(2) improve theories in exploration techniques and resource genesis.

The geochemical study of the bottom sediments of selected water reservoirs in Slovakia

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Silting up of water reservoirs by bottom sediments is a serious problem in water management. Sediments are transported to water reservoirs by rivers and cause problems connected with the reduction of their accumulation capacity. This problem can be partially solved by dredging the sedimens from the water reservoir and their subsequent application to agricultural soils. Severe contamination by toxic trace metals often makes this application impossible, since the dredged sediments may pose a risk to the environment. The dredged sediments are then commonly disposed of to land, often as a special waste. Sediments play a significant role in the remobilization of contaminants in aquatic systems under favourable conditions, and in interactions between water and sediment. The release of trace metals from sediments will depend on the speciation (i.e. metals may be precipitated, complexed, adsorbed, or solubilized) of metals and other factors, such as sediment pH and the physical and chemical characteristics of the aquatic system. Metals may be distributed in sediments as exchangeable, carbonate-bound, iron-manganese oxide-bound, organic-matter-bound and residual-bound species. The speciation of metals can be evaluated by carefully choosing the extracting solutions and digestion conditions. There is also a need for an investigation of metal sorption and desorption, because these processes most likely control the concentration of metals in the aquatic system, and hence its bioavailability and potential toxicity.

However, land-disposed contaminated dredged sediments are subjected to drying and oxidation. As a result, disposal of dredged sediments is likely to change the redox potential, pH and the organic matter decay rate, which are the most important factors controlling metal mobility. For further treatment of the land-disposed dredged sediments it is important to investigate qualitative changes in the sediment properties and in the mobility of metals during drying on the earth's surface. Taking the above into account, the objective of this study was to assess contamination by metals of three different bottom sediments from water reservoirs of Slovakia and to compare copper sorption and desorption before and after drying. The changes in sediment redox potential and pH were also studied. Furthermore, partitioning of the selected metals among the various solid phases of the air-dried sediments using the modified BCR sequential extraction scheme was investigated. In order to evaluate the toxicity of the investigated sediments, a toxicological test was also performed.

Analyses of heavy metals in the sediments were conducted on bottom sediments collected from three sampling areas – two in the Ružín water reservoir and one in the Veľké Kozmálovce water reservoir. The experiments and toxicological tests were carried out on three mixed samples from these reservoirs. The bottom sediment samples were taken at two sites of the Ružín water reservoir. One sampling site was located where the Hornád River flows into the water reservoir and the other was at the mouth of the Hnilec River. Former mining activities in the Hornád and Hnilec basins are the main source of contamination of the collected bottom sediments by metals. The Veľké Kozmálovce water reservoir lies on the Hron River near the village of Starý Tekov. The bottom sediment sample from this water reservoir was taken at the mouth of the Hron (VK sediment).

For analyses of heavy metals air-dried sediment samples were used. The total metal contents of 12 elements – As, Be, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Sb, V and Zn – were investigated in the sediments. The results of analyses were compared with the limits permitted by the legislation. Toxicological tests were conducted with the methods described in detail in Slovak Technical norm STN 83 8303 using organisms *Daphnia magna* and *Scenedesmus quadricauda*. For the sequential extraction experiment air-dried sediment samples were used. Originally, this protocol consists of three steps, however, two more steps were added to the protocol in this study – distilled water (step 1 of the extraction) and residual fraction (step 5). For the comparison of copper adsorption between the original anoxic sediments and treated by drying, two sets of batches were prepared.

Arsenic and mercury were the main contaminants present in the sediments, followed by Cu, Sb, Zn and Pb. This confirms that the bottom sediments are highly contaminated and due the Slovak legislation cannot be used for application to the agricultural soil. The major mineralogical phases in a < 2 µm fraction of the sediments were quartz and clay minerals (kaolinite, chlorite, smectites, illite).

The sequential extraction results indicated that most of the As present in the sediments was associated with the residual phase, followed by the oxidizable phase, likely due to a relatively high organic matter content in the sediments. On the other hand, the greatest amounts of Cd and Zn were extracted in the second and third steps of the sequential extraction protocol. This indicated that Cd and Zn were mostly associated with the exchangeable and reducible phase. All toxicological tests done with Daphnia magna were negative. For the HO and VK sediments the tests were positive when done with *Scenedesmus quadricauda*. Although the contamination and positive toxicological response to *Scenedesmus quadricauda* of the investigated sediments were identified, the results of toxicological tests done by the methods described in detail in Slovak Technical Norm STN 83 8303 classify this material as a harmless waste.

Adsorption of Cu^{2+} was described by the Freundlich and Langmuir equation. Adsorption of Cu^{2+} to the air-dried sediments with the exception of the Hornád sediment was significantly lower when compared with Cu^{2+} adsorption to the original sediments. Simple calculation using the PHREEQC speciation program showed the greatest proportion of the precipitated Fe oxyhydroxides (ferrihydrite, goethite and lepidocrocite) in the sediments after drying, which may co-precipitate with Cu^{2+}.

This study revealed that drying and oxidation of the anoxic bottom sediments dredged from water reservoirs had an influence on the adsorption-desorption behaviour of Cu^{2+}. Generally, the adsorption capacity of the air-dried and oxidized sediments was lower, and consequently, the release of Cu^{2+} was greater when compared with the initially anoxic sediments.

In terms of the soil and water pollution, the air-dried sediments could represent greater contamination risk as a result of enhanced release of Cu^{2+} and likely other heavy metals than the original anoxic sediments. This finding may have implications for the management of dredged sediments when disposed of to land, since their drying and oxidation after disposal leads to some changes, which in turn favour the release of heavy metals to natural waters and soils.

Tectonic dislocations of the Estonian kukersite deposit and their influence on oil shale quality and quantity

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The Estonian oil shale-kukersite deposit forms an elongated about 135 km long E–W trending lens-shaped body, in Ida-Virumaa county of northern Estonia. The width of the deposit is 45 km in the east, decreasing to 10–15 km in the west. The richest part of shale belongs to the lower portion of the Kiviõli Member of the Kukruse Stage, which formed 460.9 ± 1.6 Ma ago, at the beginning of the Late Ordovician. The maximum thickness of the productive layer is about 3 m (Kattai et al. 2000). The total thickness of the enclosing Ediacaran and Palaeozoic sedimentary strata varies from about 150 m in the north to 300 m in the south. The eroded surface of the strongly folded and metamorphosed Palaeoproterozoic crystalline basement lies at depths of 150–300 m, dipping southwards, together with the overlying sedimentary cover, with an inclination of about 3 m per kilometre.

The main geotechnical problems in mining are related to tectonic dislocations in the bedrock, including the productive layer. The sedimentary cover records the geological history of ancient Baltica and events in neighbouring orogenic zones, including the Scandinavian Caledonides and Urals. Four main compressive/transpressive events are known in the Caledonides (Roberts 2003). The oldest, Finnmarkian event involved collision of the Baltoscandian margin with an oceanic magmatic arc and subduction, with a peak about 505 Ma. This event caused a long hiatus in sedimentation during the Middle and Late Cambrian in Estonia (Pirrus et al. 2006). The opening of the Iapetus Ocean reached a maximum about 490 Ma ago. After the Trondheim event, about 480–475 Ma, Baltica started to rotate anticlockwise away from Siberia. However, the Taconian 470–465 Ma event is not clearly registered in the sedimentary record of Estonia. The continuing migration of Baltica towards the equator led to more rapid sedimentation in warmer seas, including deposition of the highly fossiliferous Estonian oil shale during the Late Ordovician Kukruse Stage. Sea level fell by 50–100 m, accompanied by regression in the Late Ordovician, correlating with Saharan glaciation. Late Silurian sediments can be found only in SW Estonia. The principal Scandian orogenesis is a product of oblique collision between Baltica and Laurentia in the Late Silurian to Early Devonian, during which the Baltoscandian margin was subducted beneath Laurentia. The Scandian thrusting and deformation affected the entire Scandinavian Caledonides and reached its peak at 407 Ma (Cocks & Torsvik 2005). Scandian deformation also affected areas far from Fennoscandia. The Mõniste–Lokno Precambrian basement uplift in SE Estonia and numerous tectonic dislocations in the oil shale basin are the result of Scandian orogeny. The following 20 Ma in Estonia were characterized by erosion and the formation of a regional unconformity. The Caledonian Solundian extensional phase occurred between 405 and 395 Ma and continued after 395 Ma (Cocks & Torsvik 2005). The Middle Devonian transgression extended across most of Estonia and possibly also a large portion of the Fennoscandian Shield. Devonian white and red-coloured sandstone (“Old Red”) was deposited unconformably on both Ordovician and Silurian strata. This rapid transgressive event was followed by gradual regression of the sea and the youngest Estonian Late Devonian bedrock occupies only a very limited area in SE Estonia. Although the prolonged 360 Ma period of post-Devonian erosion might theoretically have eroded the upper part of the crust (total thickness of about 10 km, for a rate of 0.03 mm per year), it is unlikely that the total amount of sediment removed exceeds several hundred metres. The wide development of deep karst in the oil shale deposit under the Middle Devonian sandstone sequence (Gazizov 1972) indicates that the sea level was lower and the area occupied by the current Gulf of Finland was emergent. Likely it remained above sea level until the Pleistocene glacial-related sedimentation (Raukas 1988).

The 120–300 m thick sedimentary cover is divided into blocks by linear fracture zones. The zones trending NW 320–340° and NNE 5–25° usually form narrow river valleys or lineaments defined by 25–100 km long scarps. Valley floors are up to 100–130 m below the current sea level. Some valleys are filled with Quaternary sediments. The higher density of tectonic joints in the bedrock of valley walls shows that they originated as fracture zones. The NW-trending zones are developed preferentially in the western part of the oil shale deposit, while NNE-trending faults occur mostly in the eastern part. The angular Purtse River valley follows partly along NW, partly NNE trends. In the deep Purtse and Vasavere valleys, the commercial oil shale layer has been completely eroded away.

Another important tectonic dislocation trend between NE 25° and 60° was first encountered in 1943 while drilling near the Ahtme mine. This trend is not usually expressed by valleys, although they may be parallel to chains of eskers (Viivikonna zone). The zone is blanketed by a thin (0.5 m) boulder till horizon, despite the intensity of fracturing and folding (Sõstra & Vaher 2007), indicating preglacial origin for deformation. All such zones were discovered during mining or geological study and the best-known Aseri, Ahtme, Sonda and Viivikonna dislocations have vertical amplitude varying from 5 to 25 m and lengths from 10 to 150 km (Kattai & Vingissaar 1980; Kattai 1986). The greatest dislocations are regularly spaced, about 12–16 km apart. Each dislocation is associated with open anticlinal and synclinal folds with wavelengths of 2–3 km, complicated by minor folds. Bedding on the major fold limbs dips at very small angles, not more than 1–4°, but in minor folds, dips may reach 18–45°. Smaller, 5–20 m wide open folds with amplitude of 2–3 m, as well as karst occurrences, are developed sporadically between the main zones of dislocation. Fold hinges and flexures are often complicated by strongly jointed zones or faults, including thrusts. Regular dislocations consist of 5–6 or more parallel faults with folded and fractured bedrock blocks between. Faults commonly dip towards the NW at angles of 85–55°, which is appropriate for foreland reverse fault activation associated with the Scandian phase of the Caledonian orogeny, which was centred some 600 km to the NW. Well-preserved mesoscopic folds near the present surface indicate that there must have been at least some overlying cover sequence. During the Late Silurian and Early Devonian the Baltica continent was located near the equator, so that weathering rates were rapid, consistent with widespread surface and deep karst in the Ordovician limestone–oil shale sequence, following fault zones and single joints (Gazizov 1972). Individual open joints are filled by clastic dykes (sandstone), which are also found present in the oil shale horizon, where it is covered by Devonian sandstones. Deep karst is developed only in the disturbed rocks through the entire limestone sequence, up to 30 m beneath the oil shale layer. Deep karst shows zonation, such that the inner 10–15 m of oil shale is changed to karst clay. This central zone is surrounded on both sides by a fractured zone (up to 15–20 m) and more intensively jointed bedrocks in the outer 20–30 m zone. Bedrock in the fractured zones is dolomitized, with veins containing pyrite, calcite and sometimes galena. Kerogene in shale is oxidized and of poor quality.

The deep karst occupies about 10–15% of the main dislocation zones, and in blocks between zones, especially within anticlines, oil shale losses are 1–4%. At the top of some small dome-like structures, the oil shale horizon has been eroded. In all zones of karst and dolomitization, the content and quality of shale kerogene is diminished (Sokman 2007). Cross-sections of dislocations vary considerably along strike, as does the thickness of the commercial shale layer. Fractured zones are also water-rich and blocks between faults unstable. All of these factors both reduce the quality of oil shale resources and make mining difficult or impractical. To ensure safe mining of oil shale in the deeper mines, a new detailed study of the tectonic dislocations in the Estonian oil shale deposit is needed. Accurate tectonic data in these essentially subhorizontal sedimentary hard rock sequences enable planning of optimum configuration and orientation for future mining developments and also influence the choice of mining and extraction techniques. The greatest risks for mining in the Estonian oil shale mine are within the karst zones, where hard rock has been replaced by soft masses of clay with limestone relicts.

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Postglacial seismic activity of the SE Fennoscandia and Estonia

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Studies of postglacial and recent bedrock movements in Finland and Sweden were initiated more than 25 years ago in relation to assessment of bedrock stability for safe disposal of radioactive and other hazardous waste (Kuivamäki & Vuorela 2002). These investigations showed that postglacial and recent tectonic movements continue to occur, although in a sporadic, unevenly manner, throughout the whole of the Fennoscandian Shield. Postglacial deformations are controlled partly by glacial isostatic adjustment and uplift, and partly by horizontal motion, which in Finland is directed outward from the area with the highest uplift rate (Kuivamäki & Vuorela 2002; Ojala et al. 2004). In Sweden, some 35 palaeoseismic events ($M \geq 6.0$) have been established during the last 13 000 years. Only four of them occurred in the last 5000 years, indicating present relatively low seismic activity (Mörner 2004).

Earthquakes in Fennoscandia have been historically documented as far back as the year 1375, but current understanding is largely based on seismic data collected with modern equipment during the last 20 years (Ojala et al. 2004, www.seismo.helsinki.fi). Seismic activity is concentrated offshore near the coastline of western Norway and in some onshore zones: the Swedish coast of the Gulf of Bothnia, the northern Fennoscandian postglacial fault province (Kujansuu 1964), SW Sweden, and the Kuusamo–Kandalahti–Apatity zone. About 24 historical earthquakes have been recorded in Karelia (Nikonov 2004) and 30 in Estonia (Raukas 1988) during the last 450 years, some of which have estimated magnitudes as high as 6.5. Numerous palaeoseismic dislocations have been distinguished in the Paanajärvi–Kandalaksha zone in Northern Karelia, on the Zaonezhje Peninsula of Lake Onega, in the Kalevala and Segozero zones in Central Karelia, in the Nyuhcha–Lehta zone, in the NW Ladoga zone, and also in adjacent parts of eastern Finland (Sorjonen-Ward 1993).

The seismic-related dislocations in Karelia are seismotectonic, seismo-gravitational and gravitational-seismotectonic in origin. Seismotectonic dislocations are directly related to fault movements expressed at the surface after strong earthquakes ($M \geq 6.5$), resulting in seismotectonic depressions, fault scarps and terraces, fracturing and brecciation, opening of joints, and displacement of material. Seismo-gravitational dislocations are formed as a result of seismic vibrations activating unstable blocks, rock and soil masses and causing rapid displacement of large rock masses. In Karelia, collapse of crystalline rocks, slumps and debris flows are commonly observed in unconsolidated Quaternary sediments, accompanied by deformation of layering in the basal sediments. Garvitational-seismotectonic dislocations result form movements on the fault surfaces or their passive opening, and shocks and vibration caused by seismic events. In eastern Fennoscandia many areas of rugged relief are commonly a product of displacement-related rockfalls, rock slides, blocks displaced from ledges, “rock pillars” and “rock feathers” on the slope (Lukashov 1995).

One of the most interesting places showing numerous seismic dislocations is the broad Putkozero Syncline in the Palaeoproterozoic Onega Synclinorium (Lukashov 1995). This linear syncline trends NW 330º and can be traced for 36 km. More than 150 local dislocations have been described here, including rock slides, uplifted scarps with 30 m wide seismo-gravitational rockfalls, including large (8 m x 6 m x 3 m) angular blocks. The same types of dislocations are developed in the Paanajärvi National Park, NW Russian Karelia (Lukashov & Systra 1998). Another type of palaeoseismic dislocations occurs near the River Luashtangi in the Kalevala area. This locality was originally found by A.D. Lukashov and has been studied in more detail by the authors. The Palaeoproterozoic flat-lying schistose komatiitic basalt outcrop is located at the intersection of the NW 295º and NW 335º trending regional fault zones. As a result of strong compression forces acting on the polished outcrop surface, a number of uplifted blocks have be recognized, from 5 cm x 10 cm to 10 m x 18 m in size, with vertical uplift amplitudes from 1 to 160 cm. On the uplifted blocks usually glacial striations are preserved.

Near Petrozavodsk and on the top the Vottovaara Hill, seismotectonic fracture zones are known, with depths up to 6 m, formed under tensile stresses. Earthquakes were also well known to the ancient habitants of Karelia, and are very accurately described in runes of the Finnish-Karelian epos “Kalevala”, collected near the town of Kalevala, in Karelia.

The authors have undertaken microseismic investigations in the Republic of Karelia in the places displaying an extensive range of postglacial fault motion and seismo-gravitational dislocations. Monitoring was carried out on outcropping surfaces of sites with a local seismic network based 3/6 points, separated by distances of 100–300 m, using a factor of transformation for the seismic channel of ~ 4 × 105 V/m/s in a frequency range 0.5–40 Hz (Spungin et al. 1998). Duration of monitoring varied between 5 and 17 days and nights at different sites. Relations between amplitude-frequency characteristics and distribution of natural microseismic (microcrashes, microearthquakes from –2 power classes) events in block structures and current tectonic activity were studied. Microseismic events registered at different sites are characterized by a wide spectrum of frequencies, each site having specific amplitude-frequency characteristics that are caused by both inherent structure of the rocks and specific features of the current geodynamic stress regime. It is inferred that the frequency of microseismic event signals in the zones of extension is lower than in the areas of compression. The spatial distribution of microseismic events epicentres connected with modern block structure mark zones of active rupture (Spungin et al. 1998). The mode and intensity of microseismic events are related to uneven distribution of neotectonic activity in the region. At the Paanajärvi and Luashtangi sites, the maximum intensity of microseismic events (about –1 or 0 power classes) did not exceed 15 in an hour, whereas at Putkozero there were marked periods when the intensity of microseismic events exceeded 250 per hour.

In the Palaeozoic sedimentary bedrock of Estonia the seismic dislocations can only be distinguished in large outcrops. Some block displacements and open joints, typical of those occurring after earthquakes, are known in the limestone on the Pakri Peninsula and Saaremaa Island. Osmussaar Island was in the epicentre of the strong earthquake of 25 October 1976.

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The Middle/Upper Ordovician phosphorites in the Łysogóry Unit (central Poland) – response to sea-level rise

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The uppermost Middle to lower Upper Ordovician sedimentary record in the Łysogóry Unit (northern Holy Cross Mts., Central Poland) is composed of thin-bedded grey–green lime mudstones, marls, limestones and shales, referred to as the Bukowiany Formation. The biostratigraphic data indicate that this succession corresponds to the uppermost Llanvirn and lower/middle Caradoc time interval – (Aseri?) Lasnamägi to Idavere Baltoscandian stages (see Trela 2006 and references therein). However, in the eastern part of the Łysogóry Unit (Pobroszyn), phosphorite beds and nodules are a common lithotype within the Bukowiany Formation, which is represented by a 3.4 m thick succession. The base of this unit is marked by a conspicuous phosphorite horizon (up to 20 cm thick), which reveals two stratification patterns: 1) a condensed bed with tiny phosphate stromatolites and 2) a phosphorite conglomerate bed composed of massive and stromatolite phosphate clasts. The winnowing and reworking processes were principle agents controlling the sedimentary regime and accumulation rate during deposition of this interval. The overlying sedimentary record reflects fluctuation in sedimentation rates and sedimentary conditions, i.e., nucleation of a phosphate phase at the sediment–water interface, which led to the formation of thin- to medium-bedded phosphate-rich layers and nodules. The phosphate sediment in the Bukowiany Formation marks a significant reduction of the sedimentation rate favouring the accumulation of authigenic phosphorus, whereas the accompanying sediment was deposited under conditions of relatively continuous sediment accumulation rate. A thick phosphorite horizon (50 cm) occurs at the top of the Bukowiany Formation in Pobroszyn. It consists of four beds indicating conditions of significant sediment starvation. The occurrence of phosphatized tiny stromatolite mats and nodules indicates that benthic microbial communities played an important role in the redistribution and concentration of phosphate fraction during deposition of the Bukowiany Formation. The microbes may control the chemical composition of pore waters and indirect precipitation of phosphate near the sediment–water interface through fluctuations of redox boundary below the microbial colonies owing to direct coupling of iron reduction with organic-carbon oxidation (Krajewski et al. 1994; Soudry 2000). The stromatolites formed mats stabilizing the underlying sediment in a relatively shallow-water marine environment. The gentle bottom currents kept these mats close to the sediment–water interface where they were subjected to early mineralization and subsequent reworking by high-energy events producing the conglomerate beds.

Eastward from Pobroszyn, the thickness of the Bukowiany Formation decreases to 12 cm in the Daromin IG-1 well, where this unit is represented by an extremely condensed phosphorite bed corresponding to the upper Llanvirn (Aseri? and Lasnamägi Baltoscandian stages). This bed shows minor discontinuities overlain by carbonate and phosphate coated grains, phosphate and carbonate rip-up clasts, silt-size quartz grains and subordinate carbonate skeletal fragments.

The stratigraphic record indicates that deposition of the Bukowiany Formation commenced in response to a sea-level rise, which started in the late Llanvirn (Nielsen 2004). The highly condensed phosphorite bed at the base of this succession in the Pobroszyn section and Daromin IG-1 well marks a major environmental change, which occurred after the prominent sedimentary break. It seems reasonable to correlate the base of the Bukowiany Formation with a sequence boundary, and the overlying phosphate-rich succession with transgressive to highstand sea level stand. However, the topmost phosphorite horizon appears to represent a new transgressive event and associated reduction of the sediment accumulation rate. The abundance of various phosphate occurrences (pristine and reworked) in the Bukowiany Formation coincides with the development of mesotrophic ecological conditions on the Mójcza submarine palaeohigh in the adjacent Małopolska Massive (Trela 2005).

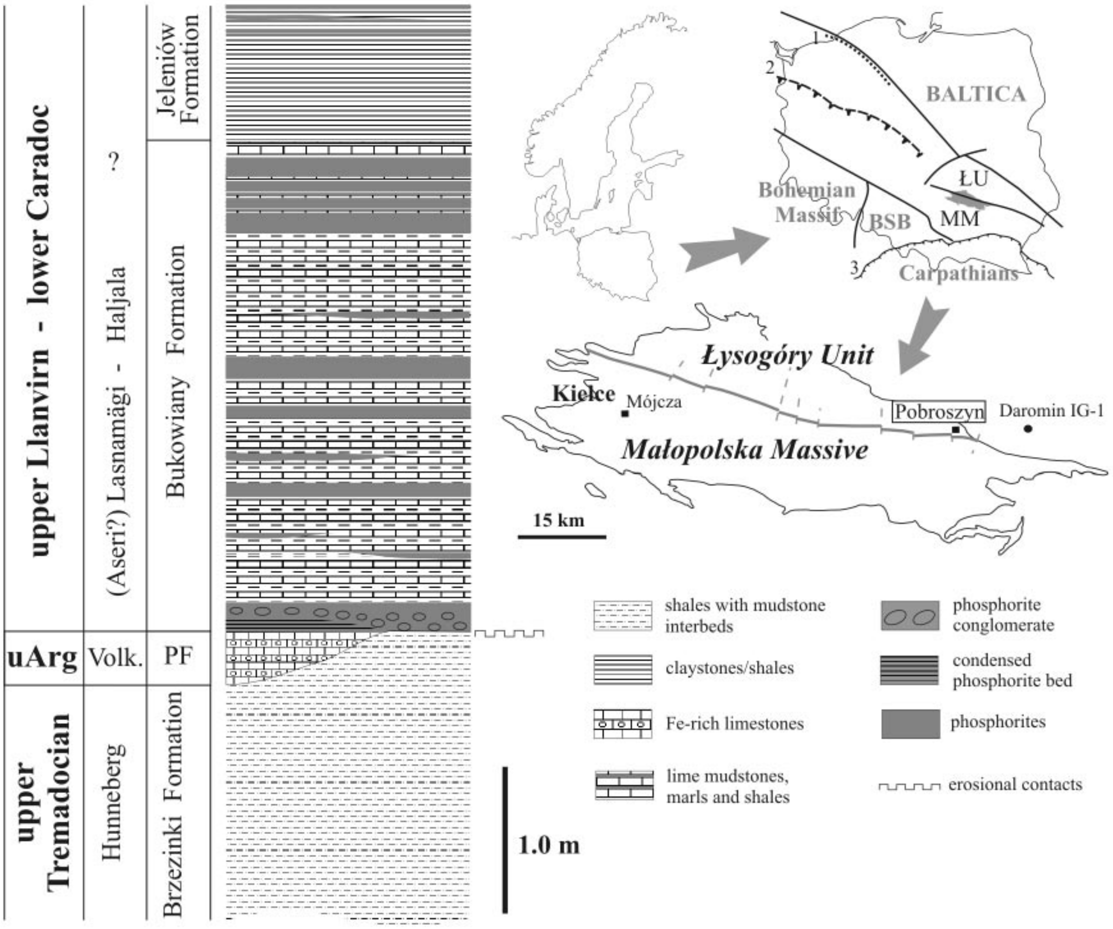

Fig. 1. Detailed lithologic and stratigraphic section of the Ordovician in Pobroszyn (lithostratigraphy after Trela 2006); uArg – upper Arenig, Volk – Volkhov, PF – Pobroszyn Formation, BSB – Bruno-Silesian Block, ŁU – Łysogóry Unit; MM – Malopolska Massive; 1, 2, 3 – respectively: Caledonian, Variscan and Alpine fronts.

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Future of oil shale mining

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Estonian power industry is based on oil shale mining. Compared to other countries, the total amount of reserves and production capacity are not high but these are high per area or per number of inhabitants. Today, the most difficult task is to find compromise between the needs of economy and fears of mining influence.

Currently, Estonia is an independent energy producer thanks to the existing oil shale deposit and favourable mining and processing conditions. Due to environmental restrictions, social pressure and deeper bedding of oil shale in potential mining fields, the testing of high-productive, environmentally friendly, mechanical mining is needed for successful continuation of independent energy supply (oil shale) for an EU state, Estonia. The situation in the EU energy market will change in the nearest future. The decreasing energy import to Estonia will be favourable for the European energy market. A new flexible and powerful mining technology will guarantee the independence of the Estonian energy sector.

The development of mining machinery and mining technology by selective mining will improve the environmental situation in Europe and the Baltic Sea region – the CO_2, ash and water pollution will decrease. To avoid a potential problem of non-utilizable waste in stockpiles of mine areas, selective mining leaves non-conditional rock mass in mined-out underground areas.

It is intended to develop a research programme for designing cutting tools/drums with a minimum cutting tools consumption and machine down time. The new design of cutting drums will lead to improved cutting and loading efficiency, with less fine rock and dust. It is an important factor for ensuring the safety of mining operations. The results of this work will be taken into account in the design of a continuous miner. Easy maintainability of the machine is another important factor for reducing maintenance time/costs and enhancing the reliability of the equipment.

Almost half of the oil shale mined in Estonia is excavated in surface mines with open cast mining technology. The economical indexes of open cast mining surpass the underground ones by 1.5–2.5 times.

In spite of the low bedding depth of oil shale, underground mining has replaced surface mining.

The geological modelling and mine design and planning are currently developed with the aim of using the best available techniques for oil shale mining. The mining software systems like Gemcom Minex, Surpac and Encom Discover, which are most widely used in the world, are suitable tools for estimating mining and geological conditions for decision-making in the mining planning process. Via the modelling process the cycle of oil shale mining can be optimized and all stages of designing explained to the specialists and public.

Geochemistry of oil and source rocks and petroleum potential of the western part of the Baltic Syneclise

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The petroleum in the southwestern part of the Baltic Syneclise has been discovered in the Cambrian, Ordovician and Silurian rocks as well as in the fractured Precambrian crystalline rocks (well Girkaliai-2) and in the Devonian sandstones (wells Kulikovskya-1 and E6-1/84). Cambrian, Ordovician and Silurian oil-bearing complexes were distinguished on the basis of the distribution of source rocks, reservoirs, seals and oil fields.

The Cambrian oil-bearing complex is the key one in Lithuania and the Kaliningrad district of Russia as well as in the country's economical zone in the Baltic Sea. The greatest number of oil discoveries are related to it. Seventeen small oil fields were discovered in western Lithuania and a similar number, however of larger oil pools, were explored in the Kaliningrad district of Russia; therefore the paper deals only with this complex.

The reservoir properties of deposits were analysed at the laboratory of the Institute of Geology and Geography, the hydrocarbon composition of organic matter and oil was studied in the petroleum laboratory of the All-Russia Research Institute of Petroleum Geology. The gas-chromatography and mass-spectrometry and carbon isotopes investigation were applied in order to study organic matter and oil.

The Cambrian oil-bearing complex comprises the deposits of the Middle Cambrian Deimena Formation, which are widespread over the entire investigated area. The successions of the Deimena Formation are composed of quartz sandstones and interbeds of argillite and claystone. Porous and fractured-porous reservoirs are most widespread. The open porosity of rocks varies within 0.7–20% (the average value is 5–15%) and the permeability reaches 1226 mD. Most oil fields in the Cambrian rocks are associated with the elevated structures of fold type that are extending as narrow (3–5 km) belts along the elevated near-fault zones of tectonic scarps. The Ordovician argillites and Silurian clayey limestone are the seal rocks overlying the oil fields in the Middle Cambrian sandstones.

Based on the data about the type, quantity and thermal maturity of the organic matter, several petroleum source rocks intervals have been distinguished in the Palaeozoic section. In the southwestern part of the Baltic Syneclise the Cambrian argillite and clayey siltstone, Ordovician black argillite of the Mossen and Fjäcka formations as well as Silurian dark grey clayey complex of the Llandovery–Ludlow are considered as the source rocks. The organic matter of the source rocks has a very similar composition (according to the data of Rock-Eval analysis: typical marine Type II). The Rock-Eval screening pyrolysis, biomarker data, reflectance of vitrinite-like macerals and conodont colour alteration index show considerable variations of the source rocks maturity. The organic matter of the Cambrian, Ordovician and Silurian source rocks in the eastern part of Lithuania and the Kaliningrad district of Russia are immature for oil generation. It is mature and in the early stage of oil generation in the western part, and reaches the oil generation peak in the southwestern part. In some places (wells Ramučiai-1, Pajūris-1 and others) the anomalously high maturity of organic matter is caused by increased palaeo-temperatures (Zdanaviciute et al. 1997, 2001; Zdanaviciute & Bojesen-Koefoed 1997; Zdanaviciute & Sakalauskas 2001).

Cambrian oil of the eastern part of the Baltic Syneclise has a moderate density (26–42 °API) and shows low or average values of asphaltenes (0–3%) and a small value of sulphur (0.04–0.44%). The content of saturated hydrocarbons makes up 42–78%. The ratio of saturated to aromatic hydrocarbons is 2.2–5.2. The gas-chromatographic analyses of crude Cambrian oils from the Baltic Syneclise showed that the oil composition is dominated by (C_{13}–C_{19}) n-alkanes, with the maxima at C_{15} and reduced abundance in the range C_{20}–C_{35}. The ratio of odd to even n-alkanes calculated for C_{22}–C_{32} n-alkanes is close to unity. The content of isoprenoides is considerably smaller than that of n-alkanes, and their ratio is very stable (0.39–0.52). The pristane to phytane ratio is also very stable and ranges from 2.07 to 2.65 (Zdanaviciute & Bojesen-Koefoed 1997). The Baltic oils, as many Palaeozoic oils, are characterised by very low concentrations of sterane and triterpane. In general, they are characterised by prominent tricyclic triterpanes, comparatively low hopane to sterane ratios and low proportions of extended hopanes. The classification of such oils by standard biomarker techniques is often difficult.

As implied from the data on the pristane to phitane, diasterane C_{27} to regular sterane C_{27}, moretane to hopane and tricyclic hydrocarbon T_{23} to hopane ratios, properties of the Cambrian oil are more similar to those of bitumoides of the Silurian source rocks. Complicated conditions for primary migration are characteristic of the Silurian section; therefore this correlation is far from simple. The correlation between oil and organic matter of source rocks in the Baltic area is a rather difficult task. The organic matter of the source rocks has a highly similar composition (according to the data of Rock-Eval analysis: sapropelic, Type II), and contains also very small amounts of relict hydrocarbon. Considering that the formation of oil fields took place during a long geological time, the oil accumulated here could have been generated from various source rocks.

Modelling of hydrocarbon migration and accumulation processes has been used to restore stages of oil field formation during different geological periods. The start of oil generation in the Baltic Syneclise is related to the end of the Silurian, while the basic oil generation phase is thought to have occurred in Devonian and Permian times. A low rate of sedimentation in the whole area of the Baltic Syneclise and different movements of the Earth's crust have created conditions for the slow formation or even destruction of previously formed oil fields. During the long time of their formation, the oil fields have been continuously replenished; therefore the oil traps in the Cambrian rocks could accumulate the oil generated not only from the Cambrian, but also from Ordovician and Silurian source rocks. The oil fields are well preserved because of favourable hydrological conditions and good sealing conditions of the overlying strata.

More than 35 million tons of oil was extracted during the period of petroleum production, i.e. more than 30 years in the Kaliningrad district and 16 years in Lithuania. This amount corresponds to less than 20% of the prognostic hydrocarbon resources (190 million tons) calculated for the offshore and onshore of the western part of the Baltic Syneclise.

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