



Czech Geological Survey Abroad



Membership of the Czech Geological Survey in international organizations

AAPG – American Association of Petroleum Geologists

AGU – American Geophysical Union

CAAG – Czech Association of Geophysicists, a member of the Council of Scientific Societies of the Czech Republic (CSS), a member of the Union of Geological Associations (UGA), and an associated society of the European Association of Geoscientists and Engineers (EAGE)

CBGA – Carpathian-Balkan Geological Association

Central European Initiative – Association of the Central European geological surveys of the Czech Republic, Slovakia, Austria, Hungary, Croatia, Poland and Slovenia

CEP – ATS – Committee for Environmental Protection – Antarctic Treaty

CETEG – Central European Tectonics Group

CO2GeoNet – European Network of Excellence for Geological Storage of CO₂

EAGE – European Association of Geoscientists and Engineers

EGS Earth Observation and Geohazards Expert Group

EGS Geoenergy Expert Group

EGS Geochemistry Expert Group

EGS Mineral Resources Expert Group

EGS Spatial Information Expert Group

EGS Urban Geology Expert Group

EGS Water Resources Expert Group

ENeRG – European Network for Research in Geo-Energy

EPOS TCS GDM – EPOS Thematic Core Service, Geological Information and Modelling

EUG – European Geosciences Union

EuroGeoSurveys (EGS) – Association of European Geological Surveys

GEO – EO4MIN – Group on Earth Observation, Community Activity EO4MIN on Earth Observation Data for Managing Mineral and Non-Renewable Energy Resources

GIC – Geoscience Information Consortium, gathering the managers of informatics of 32 geological surveys around the world

GIC CE – A consortium gathering the managers of informatics of the Central European geological surveys of the Czech Republic, Slovakia, Austria, Hungary, Croatia, Poland and Slovenia

IAGOD – International Association on the Genesis of Ore Deposits

ICDP – SAG – International Continental Scientific Drilling Program – Science Advisory Group (evaluation of submitted projects)

ICL – International Consortium on Landslides

IMA – International Mineralogical Association

INQUA – International Union for Quaternary Research

International Organisation of Palaeobotany

ICS – ISOS – International Commission on Stratigraphy – International Subcommission on Ordovician Stratigraphy

ICS – ISOS – International Commission on Stratigraphy – International Subcommission on Carboniferous Stratigraphy

ICS – SDS – International Commission on Stratigraphy – International Subcommission on Devonian Stratigraphy

ProGEO – The European Association for the Conservation of the Geological Heritage

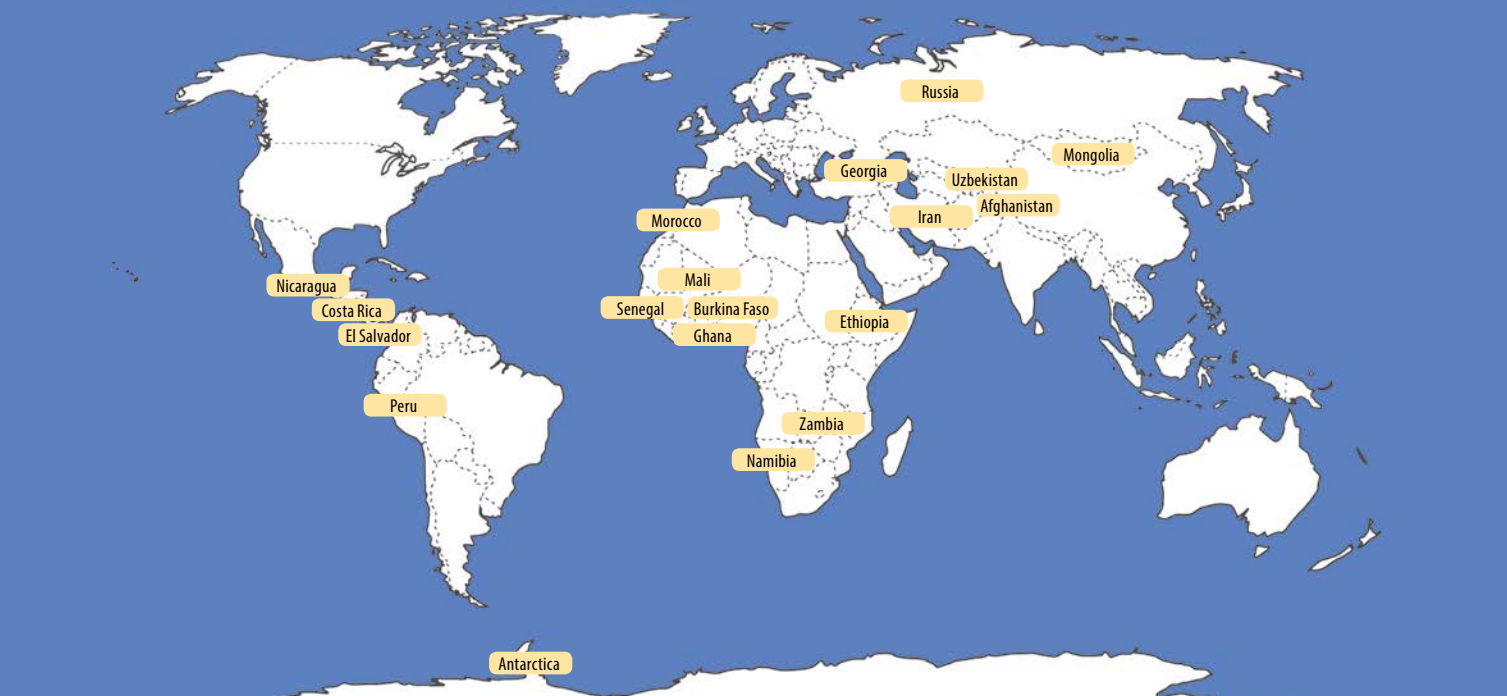
SEG – Society of Economic Geologists

SGA – Society for Geology Applied to Mineral Deposits – a scientific society gathering over 1,300 experts on geology and mineral deposits from over 80 countries around the world; the SGA publishes the prestigious journal *Mineralium Deposita*

SGS – Slovak Geological Society

SRG – The Society of Resource Geology (Japan)

UNESCO – IGCP Scientific Board – UNESCO International Geoscience Programme (Paris) – Scientific Board



Content

GEOHAZARDS	5
Geological investigation of natural hazards in Northern and Central Nicaragua	6
Integrated geological and applied investigations	10
Investigations carried out in an area of frequent natural hazards	14
Geomorphological and hydrogeological investigations in the Piura Region of Northern Peru	18
Evaluation of landslide susceptibility in mountainous parts of Georgia	22
Geohazard mapping in Ethiopia	26
Geohazard analysis in Ethiopia	30
ENVIRONMENTAL GEOLOGY	35
Impacts of mining and mineral processing on the environment in the mining districts of Namibia	36
Assessment of water resources and the environmental protection of the River Jemma basin in Central Ethiopia	40
The impact of mining and mineral processing on the environment in selected regions of Zambia	44
The impact of mining and processing copper and cobalt ores on the Copperbelt Province of Zambia	48
Monitoring dust fallout from the smelter at Nkana and environmental education of high school students at Kitwe of Zambia	52

MINERALS**57**

Assessment of gold resources in tailings left after artisanal mining in Burkina Faso	58
Tectonic development and the prediction of mineral potential in West Africa	62
Geological mapping in the Mongolian Altai	66
Assessment of exploration licences granted by the Mongolian government	70
Mineral deposit of gold and platinum at Ongon Ulaan Uul in the southern Gobi	74
Geological mapping at 1:50,000 scale and evaluation of the economic potential of a selected region of western Mongolia	76
Assistance in redevelopment of geological institutions and organizations in Afghanistan	78
Assessment of potential iron and manganese ore deposits in Iran	82
Investigation of platinum group elements (PGE) in the gold and copper deposits of Uzbekistan	86
Investigation of the distribution of platinum group elements (PGE) in the Polar Urals	90

EDUCATION**95**

Training of geologists from the Geological Survey of Iran in geological mapping at a scale of 1:25,000	96
Improving the quality of higher education in Earth sciences, particularly in combating geohazards in Ethiopia	100
PanAfGeo: Increasing geoscience knowledge and skills in African geological surveys	104
New geoscience methods for enhancing the quality of postgraduate studies in Ethiopia	108
GEOCHIM/UNESCO: Postgraduate course in methods of geochemical exploration and their environmental applications	112

RESEARCH AND DEVELOPMENT**117**

Back-arc volcanism in El Salvador and Nicaragua	118
Crustal evolution of the Kaoko orogenic belt	120
Investigations of the northern part of the Antarctic Peninsula and James Ross Island	122
Glacial retreat on the northern part of James Ross Island	126
Study of the mechanisms of continental crust formation and evolution of accretionary orogenic systems in Mongolia	130

PROJECTS**134**

Geological projects abroad have always been an integral part of the activities of the Czech Geological Survey. During its century-long existence, our institute has gained an excellent reputation at home and abroad based on thorough geoscience knowledge, which it has employed in its activities not only for the benefit of Czech society and government but also in hundreds of projects abroad, particularly in developing countries. The domain of CGS experts includes primarily geological mapping, mineral exploration, natural disaster prediction and also evaluation of negative environmental and human health impacts due to the mining and processing of mineral resources. The extensive educational activities that our employees devote themselves to over the long term deserve mention as well.

This publication lists only the most significant projects carried out by the CGS during the two decades of the new millennium in nearly 20 countries around the world. They include the Czech Republic's Foreign Development Cooperation projects in Nicaragua, Costa Rica, El Salvador, Peru, Zambia, Namibia, Burkina Faso, Georgia, Mongolia or Afghanistan, which were funded by the Ministry of the Environment and the Ministry of Foreign Affairs and later by the Czech Development Agency. They also involve R&D and grant projects in Central America, Zambia, Namibia, Antarctica, Uzbekistan or Russia. Recently, the CGS focused on activities in Ethiopia, involving the PanAfGeo training project for African geological surveys, which was funded by the European Commission, and also projects focused on geohazard research. Despite the fact that the cooperation with this country has recently subsided slightly due to its political situation, Ethiopian development projects will continue in the coming years and other African countries seem interested in cooperating as well. Along with these activities, the publication also briefly mentions some bilateral cooperation projects and foreign commercial contracts, for instance, in Iran or Mongolia. The projects mentioned are divided according to five areas of focus – geohazards, environmental geology, minerals, education, and research and development. Each project briefly states its objectives, scope, results achieved, and sources of funding.

The foreign activities of the Czech Geological Survey demonstrate a high level of scientific knowledge, and the project results are valued highly by the government authorities of developing countries, which underscores the Czech Republic's reputation within the international community. Many CGS experts continue to work abroad, and some geologists have even successfully served as diplomats in Africa, Australia, Pakistan or Latin America. International cooperation in the development and application of geosciences is undoubtedly an effective tool for deepening understanding between countries and nations as well as for maintaining a global view regarding Earth science, which is also fortified and expanded by these projects. CGS's vision is based on continuing these activities and providing high-quality geological data and consultancy to all state authorities for use in decision-making regarding a strategy for rational use of natural resources as well as for mitigation of natural disaster impacts at home and abroad.

In conclusion, I wish to thank all my colleagues participating in our foreign projects, because the success of these projects is the result of their enthusiasm and highly erudite work.



A handwritten signature in blue ink, appearing to read 'Zdeněk Venera', written in a cursive style.

Zdeněk Venera
Director of the Czech Geological Survey



In January 2009, a disastrous earthquake completely destroyed the village of Cinchona and part of the Volcan Poás National Park. The area most affected is hilly and formed by weathered Tertiary volcanites. These phenomena were responsible for the origin of numerous landslides, destruction of roads, buildings and farmland. A reconnaissance and preliminary investigation of landslide areas and monitoring of their broader environs were undertaken by the Czech team under the auspices of the Foreign Development Cooperation programme of the Czech Republic as agreed with the Czech Embassy. Photo by P. Hradecký.

G E O H A Z A R D S

The geologists of the Czech Geological Survey are engaged in a number of countries that are affected primarily by volcanic activity, earthquakes or landslides and also by other geohazards associated with processes occurring in the Earth's rock environment. These phenomena may not be caused solely by natural processes but also by human activity. The work conducted by our experts in these impacted areas strives to anticipate geohazards and, if need be, to recommend measures to mitigate their consequences. Such projects also include the transfer of experience to local geologists and specialized mapping activities.

2004–2009

Geological investigation of natural hazards in Northern and Central Nicaragua

■ Crater of the country's most active volcano – Cerro Negro.
Photo by J. Šebesta.



The development cooperation between the Czech Geological Survey and the Nicaraguan institution INETER (Instituto Nicaragüense de Estudios Territoriales) is one of the longest lasting programmes during which a number of projects have been carried out since 1997.

Nicaragua is frequently faced with the consequences of natural disasters. During the last few years several non-governmental organizations have been involved in projects concerned with the reduction of the socio-economic consequences of natural disasters that mostly affect the rural population. However, in order to assess the vulnerability of endangered areas, it is of vital importance to understand the geological structure of the given region and the types of rocks and their composition so that an assessment can be



■ In April 2009, a team of Czech and Nicaraguan geologists analyzed the causes of an earthquake that damaged part of the town of San Juan del Río Coco and frightened the local population. Earth tremors lasted for a few days and are believed to have been caused by tectonic movements in the area where the Tertiary volcanic belt of Central Nicaragua is in contact with the crystalline complex of Northern Nicaragua. Photo by P. Hradecký.



made of their susceptibility to weathering and slope failure. Geomorphological analysis is also very important. Integration of this knowledge enables the classification of different areas in terms of their susceptibility to geological hazards and other phenomena. This then forms the basis for land-use planning and preventive measures. Czech geologists have been occupied in this field of investigation in Nicaragua for many years.

During the years 2004–2009, Czech geologists worked in the central and northern parts of the country in mountainous terrain where access proved very difficult. Numerous areas vulnerable to slope failure, landslides, flooding, rock falls and catastrophic erosion were identified. Access for the investigation of the structure and geology governing these hazards in the area close to the border with Honduras had to be undertaken in coordination with the Nicaraguan army because of minefields remaining after the Civil War. The geological study was spontaneously enlarged to include investigation of the area of San Juan del Río Coco where a series of seismic shocks took place in 2009.

Numerous data on volcanic terrains as well as on geologically older rocks were acquired during the investigation. The procedures for the declaration of the Río Coco River near Somoto town as a Geopark have also been continuing.

Interim and final reports, maps and other relevant materials were handed over to the Nicaraguan counterpart at the headquarters of INETER in the capital Managua, and a seminar devoted to the results obtained as a result of the investigation was organized during the final meeting. The results of the Czech-Nicaraguan cooperative project will be incorporated in reports defining the geological hazards in individual districts and provinces of the country.

■ << The Río Coco, otherwise known as the Coconut River, is the longest river in Central America. To the west of the small town of Somoto in Madriz Province it has carved an impressive canyon in Tertiary volcanic rocks – ignimbrites – that was described recently by Czech geologists in 2004. The Nicaraguan authorities, together with Czech specialists are now planning to designate this canyon a Geopark. Photo by P. Kycl.



■ Ash cloud from a phreatic eruption of the San Cristóbal Volcano in the Pacific mountain range of Marrabios. Photo by P. Hradecký.

2007–2009

Integrated geological and applied investigations

■ The main crater of the active Poás Volcano (2,711 m), which continues to threaten the nearby urban area of San José – Alajuela. Photo by P. Kycl.



The major part of the work undertaken by the Czech Geological Survey in this country took place from 2007 to 2009 in cooperation with the Dirección de Geología y Minas at San José. The aim of the project was to analyze and assess the geological structure in areas of Cenozoic volcanites and Mesozoic sediments where landslides, floods and also contamination of surface waters by pollutants from the abandoned mine and mineral processing plant at Bellavista were frequent in the past.

■ Collecting water samples from the crater lake of the Poás Volcano for analyses. The water has a pH value of 0. Photo by P. Kycl.

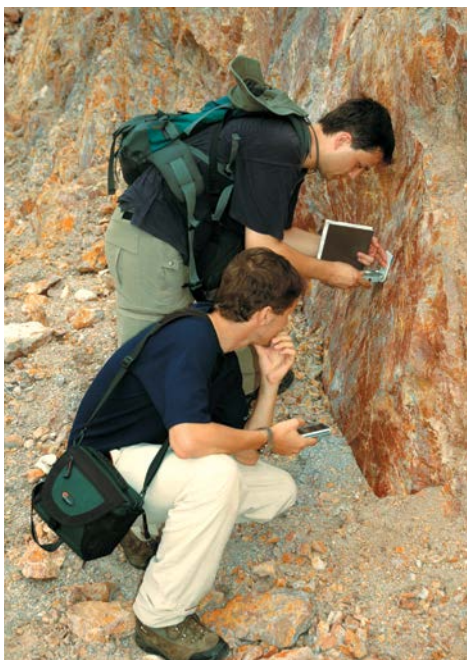




■ The dacite dome of Cerro la Cruz in the Montes del Aguacate (Avocado Mountains). An example of dynamic volcanic topography in the landscape formed by Quaternary volcanism only 1.5–1.7 Ma old. This was accompanied by active tectonic movements often resulting in landslides. Photo by V. Žáček.

The project contributed to a better knowledge of the sequence of volcanic events and the stratigraphy of the volcanic deposits and sediments in the area of interest. A proposal was made for a study of the geological structure and other phenomena in the Cinchona area that was affected by a catastrophic earthquake in 2009.

Thematic maps at 1:50,000 scale were compiled for the area of Cordillera Tilarán (Cerranías de Abangares, Montes de Oro) in the Cenozoic volcanic chain and of these, the geological maps covering the topographic sheets of Miamar, Chapernal and Juntas were published. All the results of the project were compiled in GIS form and submitted to the relevant governmental authorities for planning purposes.



■ < Measurements of faults and small deformations in andesite strongly altered by hydrothermal activity in the Cordillera de Tilarán Mountains near the town of Miramar. This area is extremely prone to catastrophic landslides and it was chosen for investigation during the Czech project. The shapes, dimensions and number of failures are influenced by a range of factors such as the inclination of the slopes, the amount of atmospheric precipitation, the type of bedrock, the occurrence of faults, fracture and zones of alteration, and the degree of weathering and frequency and strength of seismicity. Interpretation of all the acquired data enabled the places most threatened by landslides to be identified. Photo by V. Žáček.

■ > Following the catastrophic landslide at the last active mine at Bellavista in autumn of 2007, the Costa Rican administration prohibited further gold mining. However, hundreds of families still continue illegal and extremely dangerous artisanal mining for gold in the Juntas de Abangares region. The local authorities turn a blind eye to these operations because of the lack of other job opportunities. Photo by P. Kycl.



2003–2005
2007–2009

■ Faults in the
Holocene rhyolitic
ignimbrites of the
Ilopango Caldera.
Photo by P. Hradecký.

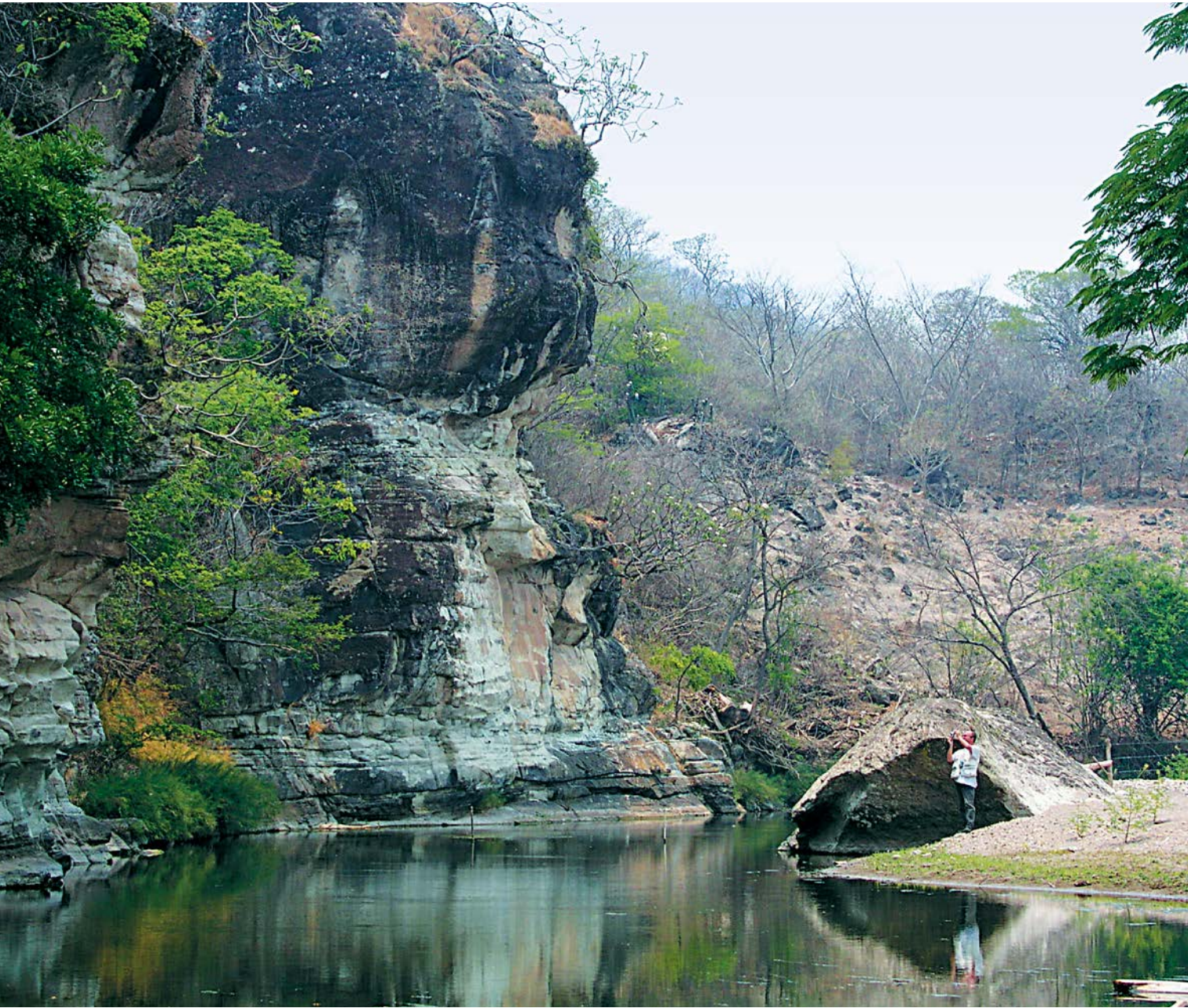
Investigations carried out in an area of frequent natural hazards



The smallest country in Central America is frequently faced with the consequences of natural disasters such as floods, eruptions of local volcanoes (Santa Ana volcano), earthquakes and landslides (city of San El Salvador). When compared with the other countries of Central America, the extent of deforestation to create farmland and the density of population (304 inhabitants per km²) make it particularly vulnerable to natural disasters. The Czech geological projects were carried out in cooperation with the Servicio Nacional de Estudios Territoriales (SNET) during the years 2003–2005 in the central, eastern and northern sectors of the country. The geological phenomena responsible for natural hazards were identified and the results were compiled in the form of printed and digitized editions of geological maps at a scale of 1:50,000 and

■ Czech experts making measurements in the field to obtain basic engineering data necessary for remedial work aimed at eliminating landslides on a cutting in the freeway around the capital of San El Salvador. Photo by J. Šebesta.





■ In the tectonically complicated Metapán zone on the northwestern border of El Salvador with Guatemala it was necessary to define the stratigraphy of both Lower Cretaceous sediments and the Neogene volcanites. The photograph shows an outcrop of dacitic ignimbrite located on the Guatemalan side of the border. Photo by P. Hradecký.

handed over to the San El Salvadoran counterpart for further evaluation and planning purposes.

The second stage of the cooperative programme took place during 2007–2009. This was focused on the capital city and its environs. The activities included geomorphological and engineering-geological studies as a basis for planning of land-use by OPAMSS (Planning commission of the capital San El Salvador). The field work was supplemented by numerous seminars and workshops at which the results of the project were presented. After the project was completed, one of the counterpart El Salvadoran engineering geologists who participated in the project travelled to the Czech Republic to undertake advanced training.



■ Santa Ana Volcano in western El Salvador often threatens the areas of a surrounding national park and nearby villages.
Photo by J. Šebesta.

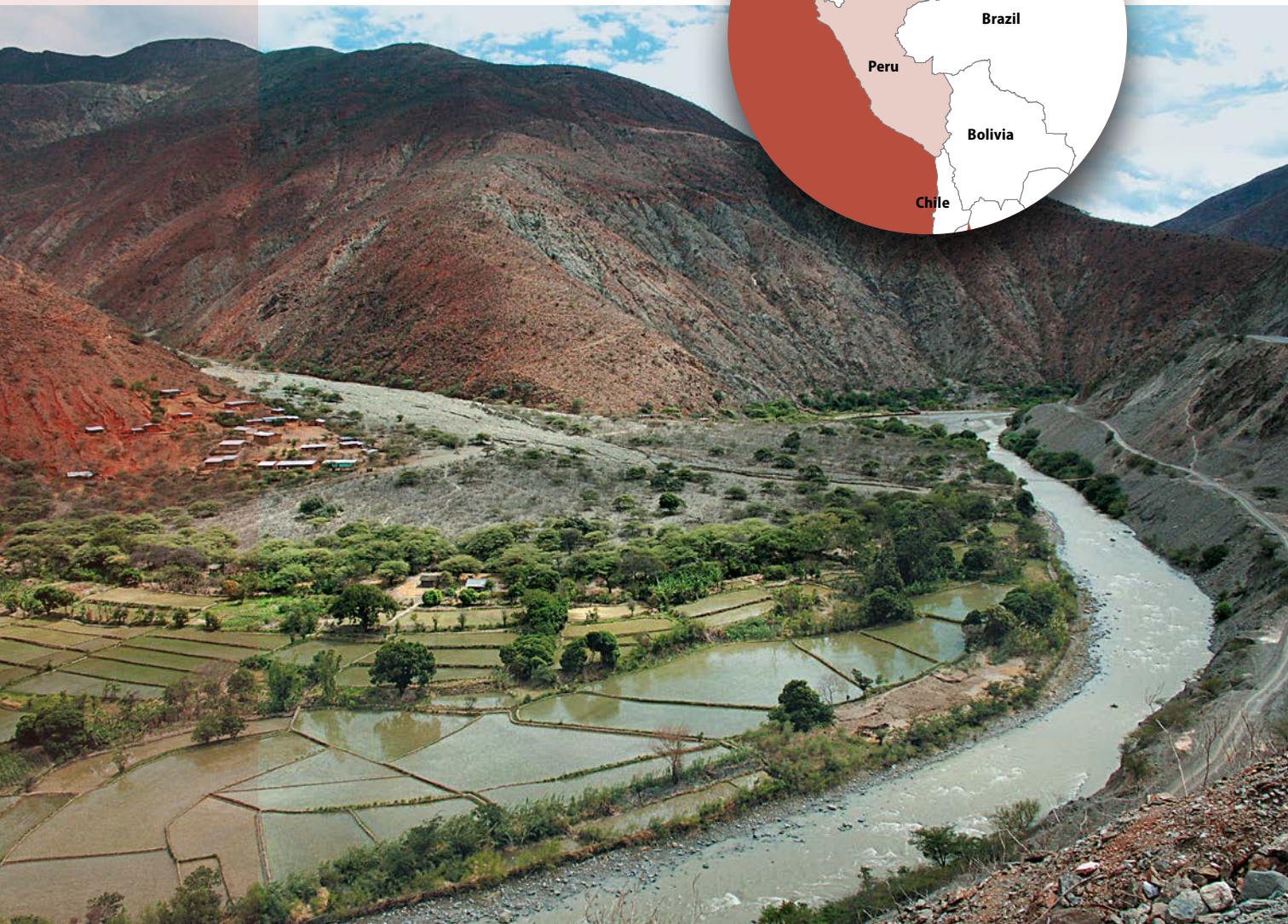
■ Geologists from the Czech Geological Survey and the counterpart organization SNET studying an outcrop on the Tertiary Juana Pancha volcano.
Photo by P. Hradecký.



2003–2006
2007–2010

■ A recent alluvial fan restricting the flow of the Huancabamba River is widely used to grow rice. Photo by D. Nývlt.

Geomorphological and hydrogeological investigations in the Piura Region of Northern Peru



In the period from 2007 to 2010, the Czech Geological Survey, in cooperation with Aquatest Ltd, undertook a project in Northern Peru that was designed to assess the vulnerability of the central and low catchments of the Piura and Chira rivers drainages to natural hazards. This project followed the assessment of natural hazards in the central and upper catchments of these rivers that was undertaken by Czech geologists during 2003–2006. The El Niño phenomenon in particular is thought to be responsible for natural disasters in the Piura Region which mostly include flooding, accumulation of sediments, soil erosion and salinization. Another task of the project was to assess the hydrogeological regime of the region, to propose methods for more efficient exploitation of ground waters and to locate additional resources of ground water.



■ Eolian processes are one of the natural hazards endangering the areas along the lower reaches of the Piura River. Here, the sand dunes are migrating at a rate of a few tens of metres a year and locally making roads impassable. Photo by M. Rajchl.



■ Northern margin of the ephemeral La Niña Lake which forms during periods of flooding along the lower reaches of the Piura River. Photo by M. Rajchl.



A geomorphological map and maps of natural hazards and engineering geological zones were compiled by analysis and interpretation of satellite images and detailed field documentation. Hydrogeological studies began by studying data stored in archives, followed by field reconnaissance and sampling of ground waters and mathematical modeling. The major outputs include a hydrogeological scheme of the region, a map of the quality of surface and ground waters and estimates of groundwater reserves. The results of the project provide basic data for land-use, the sustainable use of natural resources and protection of the region against natural hazards. The project was financed from the budget of the Ministry of Environment of the Czech Republic.

■ << Right bank of the Chira River near the village of Florida. Lateral erosion of river banks is a major hazard. Photo by M. Rajchl.



■ Erosionally modified slopes of the Meseta Andina, descending into the Quiroz River basin. Photo by D. Nývlt.

■ < Large areas are covered by water during periods of flooding. Salt crusts gradually form due to evaporation in endorheic depressions. The photograph shows the extraction of salt in the Salina Grande depression, the bottom of which lies more than twenty metres below sea level. Photo by M. Rajchl.

■ < Rockfalls consisting of Talara Tablazo sediments caused by headward erosion along an intermittent stream near the village of La Tortuga. Photo by J. Šebesta.



2014–2017

■ A torrential stream destroyed part of the village of Kvemo Mleta and temporarily dammed the Aragvi River. Photo by P. Kycl.

Evaluation of landslide susceptibility in mountainous parts of Georgia



The aim of the project “Evaluation of landslide susceptibility in the mountainous parts of Georgia on the example of endangered settlements, international roads and energy conduits in the Dusheti Municipality”, conducted in 2014–2017, was to increase the NEA geological department’s ability to prevent hazards caused by slope instabilities.

The main objective focused on identifying landslide-prone areas based on newly acquired knowledge and experience involving field surveys and determination of slope instabilities, GIS modelling, and the active application of a new slope instability database, which was adapted for use in Georgia during the project.

This capability can be applied not only in land use planning and development in the region, but it also identifies areas where preventive measures should be taken



■ A drunken forest on an earthflow near Kvesheti is a clear indicator of bedrock instability. The tree trunks curve in different directions due to the slow earthflow, to which the trees gradually adapt. Photo by P. Kycl.



in order to prevent damage to existing infrastructure and population decline in the affected mountainous areas.

In connection with the installation of a pilot monitoring system, the Georgian side was acquainted with theoretical and practical knowledge in using modern monitoring systems and their link to an early warning system.

■ << Extensive landslide slope near Zemo Mleta. Photo by P. Kycl.

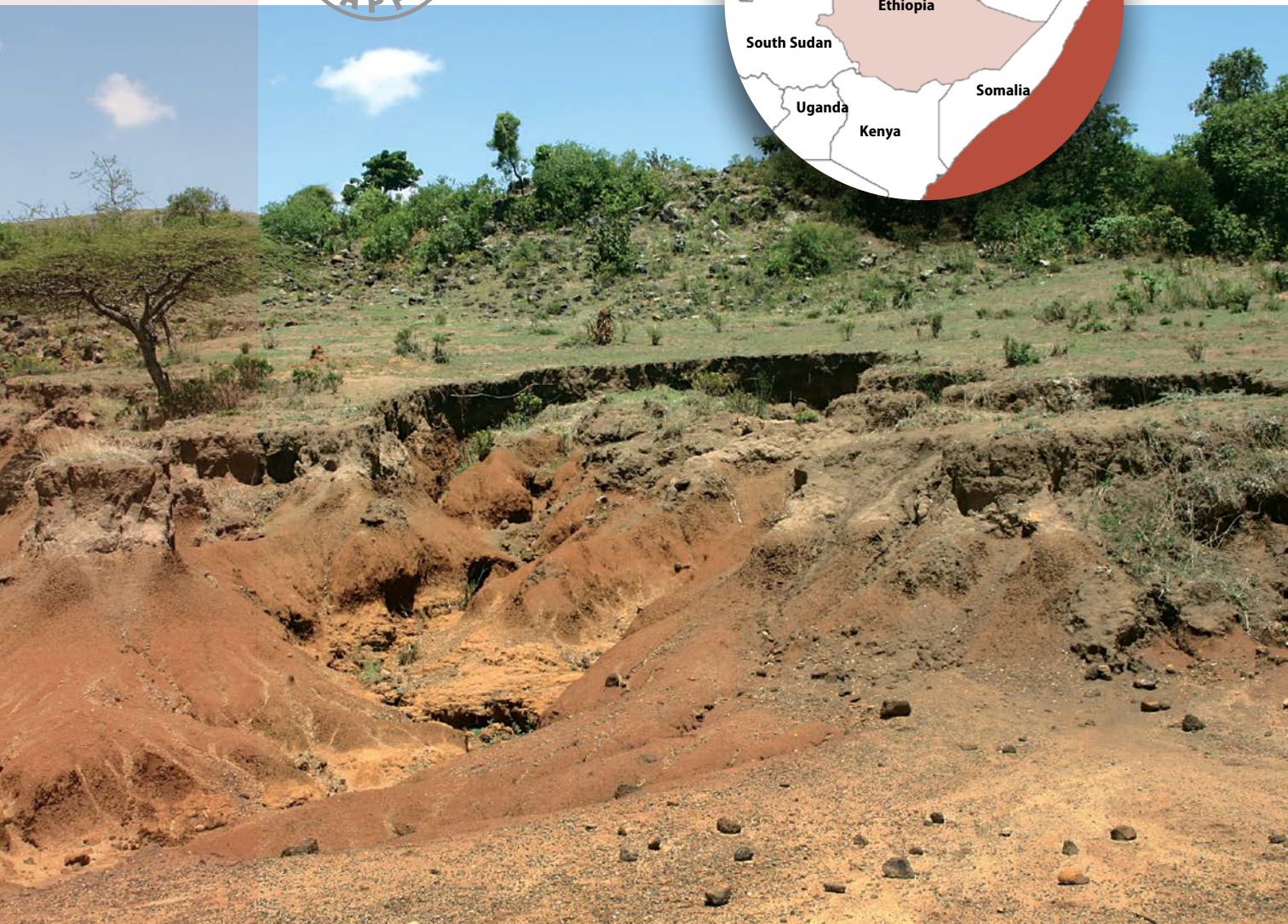


■ Shatili is a historic village in northeastern Georgia, in the former province of Khevsureti (translated as a land of valleys). It is located in the Argun River valley, 3 km from the Chechen border. Shatili was built in the 8th century on a rock and its attached dwellings create a continuous fortification. The village thus served as a fortress of strategic importance. Photo by P. Kycl.

2012–2014

Geohazard mapping in Ethiopia

■ Soil erosion is a serious threat to agricultural production. Photo by V. Rapprich.



The restructuring of the Geological Survey of Ethiopia (GSE), which took place in 2007–2009, included the establishment of a geohazard division. However, it became apparent that the GSE does not have sufficient expertise to perform tasks associated with natural hazard assessment. Another of the government's fundamental demands made upon the GSE is to accelerate the mapping of groundwater sources and to provide up-to-date information to a wide range of users. This was the main reason why, in its effort to increase its expertise in engineering geology, volcanology, seismology and hydrogeology, the GSE approached the Czech Republic with a request for assistance under the Development Cooperation Programme. The project was carried out by the Czech Geological Survey and Aquatest in 2012–2014 as a follow-up to predominantly

■ The volcanic crater of Shetan.
Photo by V. Rapprich.





hydrogeological Czech-Ethiopian projects conducted previously. As in the past, the Ethiopian side helped cover expenses in the form of subsistence allowances for Ethiopian workers during field mapping, expenses associated with off-road vehicle use, etc.

During the course of the project, 20 GSE experts received training in engineering geology, volcanology, seismology and hydrogeology, which enabled them to independently compile, edit, present and interpret actual map outputs. Hydrogeological and hydrochemical maps at 1:250,000 scale were compiled with explanatory notes for the following map sheets: Asela, Dila, Hosaina and Dolo. In addition, sample geohazard maps at 1:250,000 scale including explanatory notes for the Dila and Hosaina areas were compiled, depicting the assessed hazard level and the implications for practical land use.

■ << Documentation of a subsidence fractures. Earth fissures represent a serious and thus far inadequately studied hazard in southern Ethiopia. Photo by V. Rapprich.



■ Pyroclastic deposits of the Shetani crater. Photo by V. Rapprich.

2015–2018

Geohazard analysis in Ethiopia

■ Lateral erosion
of agricultural land
associated with
the formation of
landslides (Leku).
Photo by K. Verner.



Ethiopia is one of Africa's most populous countries with a unique history. Today, the country is a regional centre in the East African region with increasing geopolitical and economic importance. The Development Cooperation Strategy of the Czech Republic ranks Ethiopia among the priority partner countries. The cooperation with Ethiopia is built on a rich tradition of mutual relations and ongoing activities of Czech organizations.

At present, the Czech Geological Survey heads the implementation of two projects in Ethiopia, which include basic and applied geoscientific research with an emphasis on pedagogical activities and knowledge transfer to cooperating partners.



■ Formation of suffosion joints associated with tectonic faulting of the rock environment (Midre Genet). Photo by K. Verner.



The main focus of the project entitled “Study of Natural Hazards Harmful to Agricultural Production in Selected Areas of SNNPR” involves a comprehensive study and geological mapping of the rock environment with an emphasis on analysis of potential geohazards in the tectonically active area of the East African Rift System (Arba Minch, Leku, Mejo Dila). The project results serve to mitigate the detrimental impact of geological processes on agricultural production in order to ensure the sustainable use and protection of agricultural land, water sources and local infrastructure.

■ << Fault plane of the western edge of the rift system, also known as the slide (Dorze). Photo by K. Verner.



■ Documentation of geological sites with representatives of the local population (Dila). Photo by K. Verner.



A quarry for extraction of ignimbrite lies close to the town of Debre Birham. The rock is used to construct and reinforce roads in Ethiopia. Work is predominantly manual and women are often employed in crushing the rock for the production of aggregate. Photo by J. Krupička.

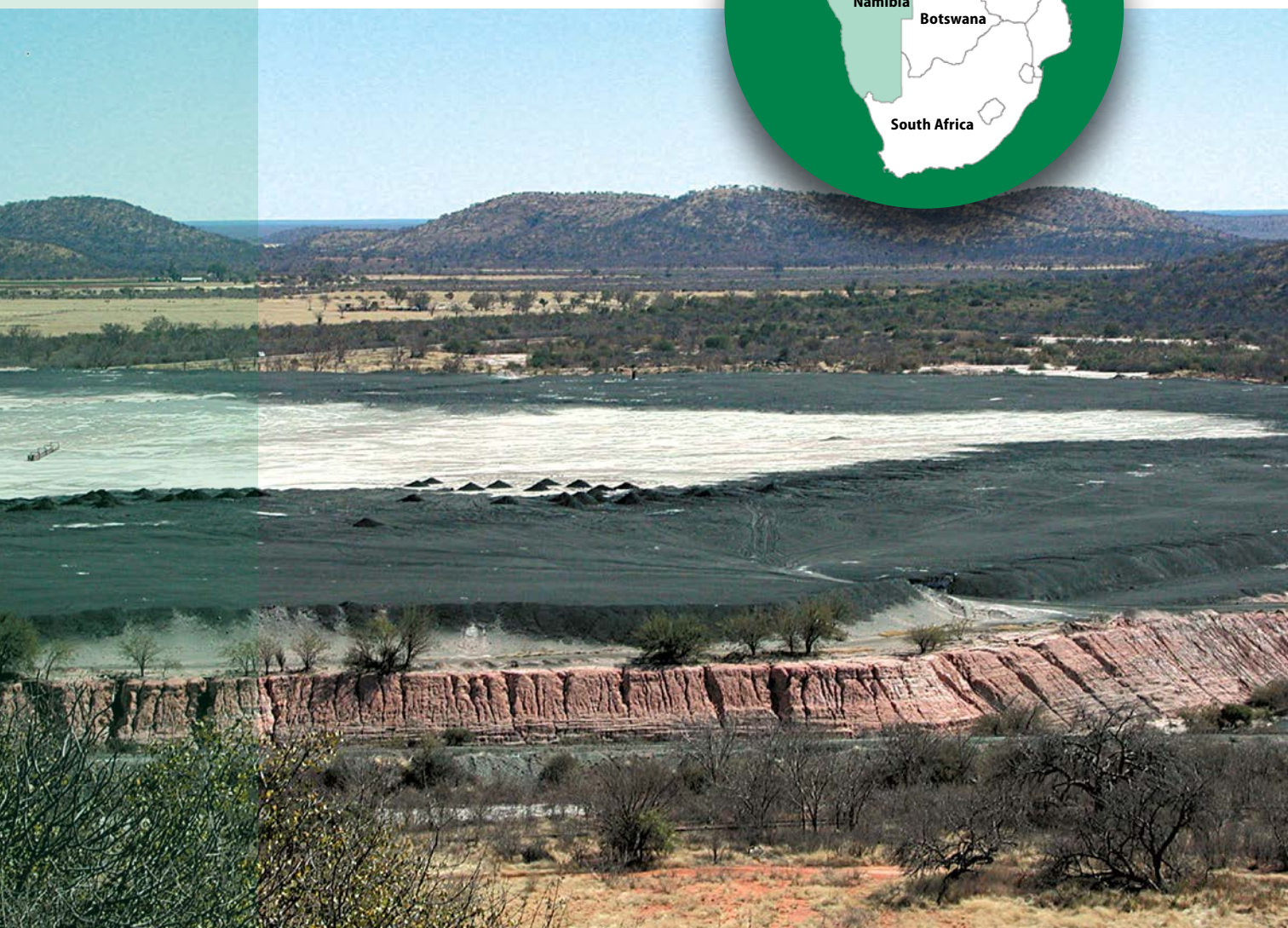
ENVIRONMENTAL GEOLOGY

Many of our foreign activities focus on solving environmental problems with the assistance of various geological branches and many related fields. These include hydrogeology, engineering and economic geology, or geochemistry. In accordance with the concept of sustainable development, we aid our foreign partners to safeguard the environment and to rationally use natural resources, including surface and ground water, in order to prevent their degradation. Attention is also paid to anthropogenic contamination of soil, water or vegetation, particularly if caused by mining or dust fallout from smelters.

2004–2006

■ Very high levels of contamination by lead, zinc and arsenic were detected in topsoil near the smelter at Tsumeb. The strongly contaminated area exceeds 20 km².
Photo by B. Křibek.

Impacts of mining and mineral processing on the environment in the mining districts of Namibia



The project was designed to assess the effect of mining and mineral processing on the environment in abandoned as well as in currently active mining districts. Because of the arid climatic conditions in Namibia, particular attention was paid to the contamination of soils and plants by dust fallout from smelters and mines and also to the assessment of the toxicity of flotation tailings stored in settling ponds. The levels of contamination of surface and ground waters, and stream sediments near tailings ponds were also monitored.

In order to determine suitable strategies for reducing the impacts of mining and mineral processing on the environment and health of the population living in mining districts, environmental-geochemical monitoring and mapping were carried out in the



■ Education and training of students from the University of Namibia in environmental studies and monitoring of contamination in mining districts affected by dust fallout were an integral part of the project. Photo by B. Kříbek.



■ A number of students are currently involved in Ph.D. theses on environmental subjects and also on projects for private mining companies or in the newly founded Environmental Department of the Geological Survey of Namibia. Photo by B. Kříbek.



■ Approximately 37% of the total number of grass samples collected from the Berg Aukas region have Pb contents exceeding the limit set in Czech standards for dry fodder. Samples of leaves and cassava tubers collected from strongly contaminated farmland showed visible signs of abnormal growth (size, shape of tubers). Most cassava leaves contained As, Pb and Zn in amounts well in excess of permissible values set by the World Health Organization. The contents of these metals in cassava tubers from the Berg Aukas region are also in excess of the standard limits for foodstuff. Photo by B. Kříbek.



Tsumeb region around the mineral deposits of Kombat and Berg Aukas (Otawi region) and around Rosh Pinah in southern Namibia. In the Tsumeb region, the impact of dust fallout from the local smelter on the contamination of soils and crops was assessed. Here, the ecotoxicity of stored wastes and the areal extent of dust fallout from dry settling ponds and from ponds containing slimes were also investigated. A study was made of the dust emitted by single mining and mineral processing operations and the extent of contamination of soils by dust fallout around the currently active Kombat deposit. Special attention was also paid to contamination of soils and vegetation in the environs of abandoned zinc and vanadium deposit at Berg Aukas because it is surrounded by cultivated farmland. The impact of dust fallout from waste dumps and from tailings ponds on terrestrial ecosystems was studied in the area of the Rosh Pinah zinc deposit which lies in the Ais-Ais Game Reserve. Education and training of local specialists and students from the University of Namibia formed an important and integral part of the project.

The Namibian project has enabled an objective assessment of the degree of regional contamination of the environment caused by mining and mineral processing at numerous abandoned and currently active mining operations. The results will be of use to the Ministry of Mines and Energy of the Republic of Namibia in framing systematic legislation for the environmental control of mining and mineral processing activities in the country. Regional authorities will be able to use the project outputs as a basis for planning land-use in contaminated areas, minimising the impact of contamination in urban areas and establishing environment-friendly strategies for future industrial developments in rural areas.

■ << An open fold in the dolomites of the Tsumeb Subgroup. Photo by B. Kříbek.



■ Outcrops of Neoproterozoic quartzites near Windhoek. Photo by B. Kříbek.

2006–2008

■ The edge of the River Jemma basin with large blocks of basalt torn from the edges. The difference in height between the upper edge and the bottom of the basin locally exceeds 1200 m. Photo by Aquatest, Ltd.

Assessment of water resources and the environmental protection of the River Jemma basin in Central Ethiopia



Ethiopia is a large country in the northeastern horn of Africa. The topography is formed by plateaux dissected by the African rift zone. Agriculture is the major economic activity which suffers from two problems: the lack of water (both surface and groundwater) and soil erosion. Because of global climate change, the amount and frequency of atmospheric precipitation on which the agriculture heavily depends has significantly decreased. Deforestation has also led to reduction of groundwater resources, while torrential rains falling on the bare land surface cause accelerated erosion of fertile soil.

Ethiopia has large groundwater resources, but these are not available to large parts of the country and only 15% of the population have access to drinking water.



■ A block of basalt at the edge of the River Jemma basin has been loosened. Leta, a geologist from the Ethiopian Geological Survey assisted by his two colleagues Janymar and Eshatu, is testing the basalt block using a Schmidt or Swiss hammer to measure the elastic modulus of the rock. Photo by J. Krupička.



■ View of the slope of the valley of the River Jemma. Outcrops of single basaltic flows can be clearly distinguished. They differ from one another by their strength and thickness. As a result of selective erosion, blocks from loosened harder layers are torn off and slide down the slope into the valley (cambering). Photo by J. Krupička.

A project designed to gather geo-ecological and socio-economic information about the surface of Ethiopia, specifically about soils and their use, surface and ground waters and geohazards such as landslides and erosion was undertaken during 2006–2008. This project was carried out by geologists from the Czech Geological Survey in close cooperation with geologists from the Geological Survey of Ethiopia and Czech experts from the Aquatest Company.

This cooperative project resulted in the compilation of hydrogeological maps, maps of surface and groundwater quality and assessment of geodynamic phenomena in the form of geohazard maps of selected map sheets. Some new wells have recently been drilled in Ethiopia to give access to drinking water, dams are being constructed to capture water from torrential rains and based on the results of these investigations and geological mapping, measures are being taken to control erosion.

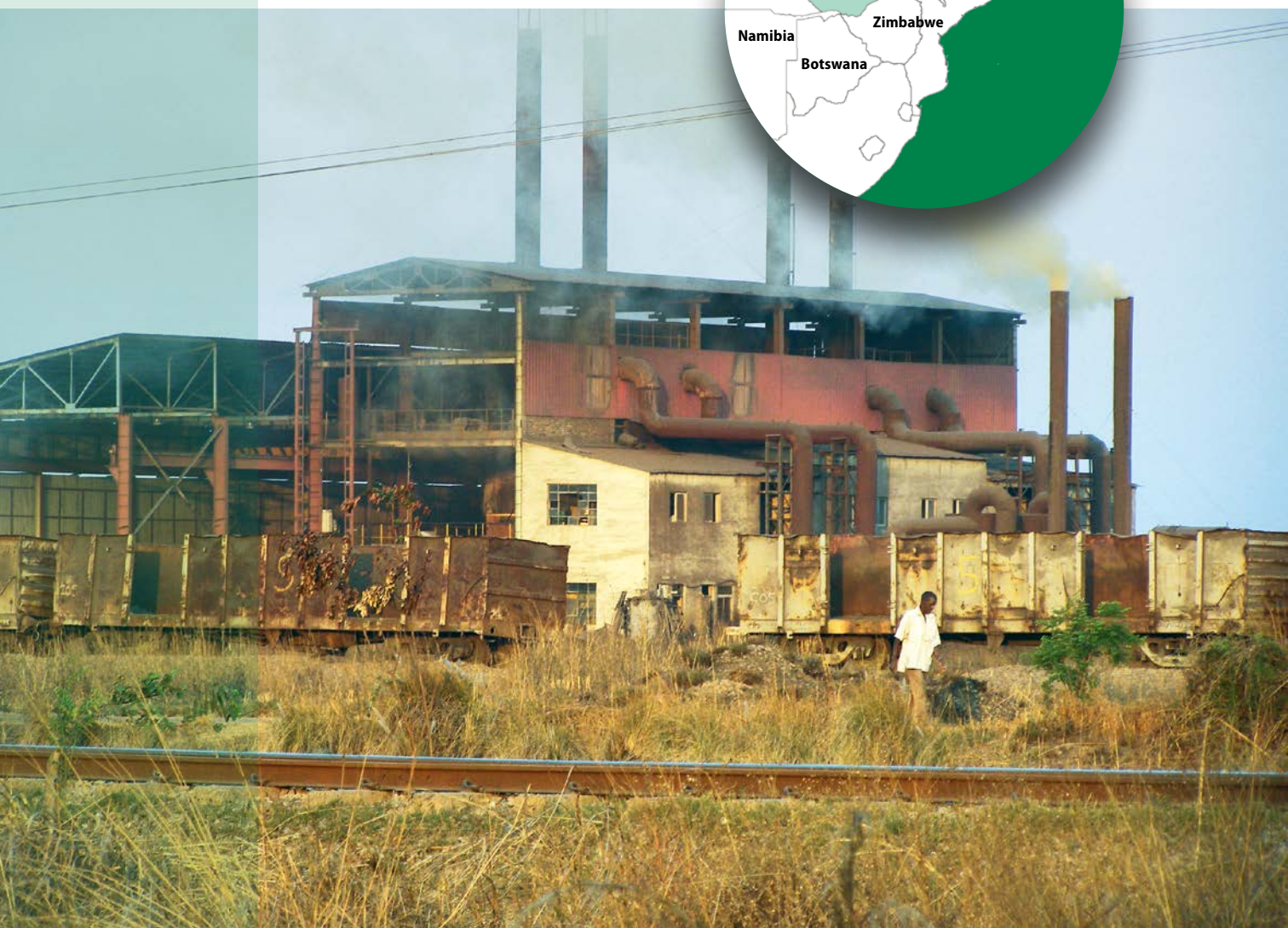


■ View of an outcrop of solid ignimbrite in the wall of the Debre Birham quarry. This rock is abundant in the Ethiopian Highlands and is extracted from numerous small and larger quarries. The material is transported and used for construction and repair of roads and other communications. The aggregate is also used for construction of rockfill dams, many of which are being built at different localities to capture the water falling during torrential rains. Photo by J. Krupička.

2004–2006
2008–2010

■ The urban area of the city of Kabwe is among the most contaminated areas in Africa. Photo by B. Křibek.

The impact of mining and mineral processing on the environment in selected regions of Zambia



The recent project that followed earlier work carried out during the years from 2004 to 2006 was designed to identify and outline the contaminated area, to assess environmental hazards and to select the most suitable environment-friendly technologies to mitigate the risks in the urban area of the city of Kabwe in the Central Province and in the urban areas of Luanshya and Ndola in the Copperbelt Province of Zambia. Field work was focused on the assessment of the degree of soil contamination around the sites of abandoned smelters and on the level of contamination of crops (sweet potatoes, cassava and corn), including the risks to health resulting from the consumption of contaminated crops. The extent and degree of contamination of stream



■ Environmental studies carried out in the Ndola area of the Copperbelt Province showed that dust fallout from local limeworks and cement works is the major source of contamination. Geochemical mapping defined the areal extent of contamination and appropriate measures to cut down gas and dust emissions were proposed. Photo by B. Kříbek.

■ > The tailings pond at Bwana Mkubwa in which toxic flotation waste is stored is considered to be a potential environmental risk to the Ndola region. Erosion of the tailings pond dam and washout of suspensions into the local streams pose the major hazard. The areal extent and degree of contamination of soils and crops in the neighborhood of the former smelter in the environs of the city of Luanshya were defined. Consumption of badly washed crops cultivated in the contaminated area is the major environmental and health risk. Escapes of sludge from broken dams of the old flotation tailings ponds place another environmental burden on this area. Photo by B. Kříbek.





■ The results of the project were used in planning the remediation of tailings ponds and for designing a system to monitor dust fallout around sources of contamination. Measures were also taken to reduce the escape and drainage of flotation tailings into the surface streams in the Kafue River catchment. Photo by B. Křibek.

sediments and surface waters were also investigated and priorities for remediation and reclamation work were defined.

Special attention was paid to the assessment of contamination of surface and ground waters due to the escape of industrial waste waters and chemical waste suspended in settling ponds at the Bwana Mkubwa plant where copper ores were processed. Because the urban area of the city of Ndola is strongly affected by dust fallout from local lime and cement works, monitoring of the area in which the volume of dust fallout exceeds the Zambian environmental standard was carried out at the request of the Ndola City council.

A long-term monitoring of the contamination of surface water and sediments of the River Kafue that drains the whole of the Copperbelt region was also carried out under the terms of the project. This prolonged monitoring enabled individual sources of contamination to be identified and an assessment to be made of the extent to which the mining companies have succeeded in cutting down the contamination of rivers by adopting appropriate measures.

Education and training of Zambian experts and students from the University of Zambia formed an essential and integral part of the project. Dissertations on environmental problems in the area were compiled during the duration of the project. The results of the project were presented to the scientific community at numerous international conferences and also during one-day seminars organized for mining companies and for the public in the city of Kitwe. Some methodological and material assistance was also provided to the non-governmental organization "Citizens for a better environment" that monitors the degree to which the mining companies comply with environmental measures introduced to combat contamination.

The project is believed to be the most extensive evaluation of the impacts of industrial contamination on the environment, not only in Zambia, but in the whole of Africa. The results enabled state and local authorities to improve their efforts to legislate and coordinate management of the environment and to increase the awareness of environmental issues among the local population in contaminated areas. The local authorities can now use the results of the project in making environmental decisions, starting with land-use planning and ending with sustainable development of local mineral resources.

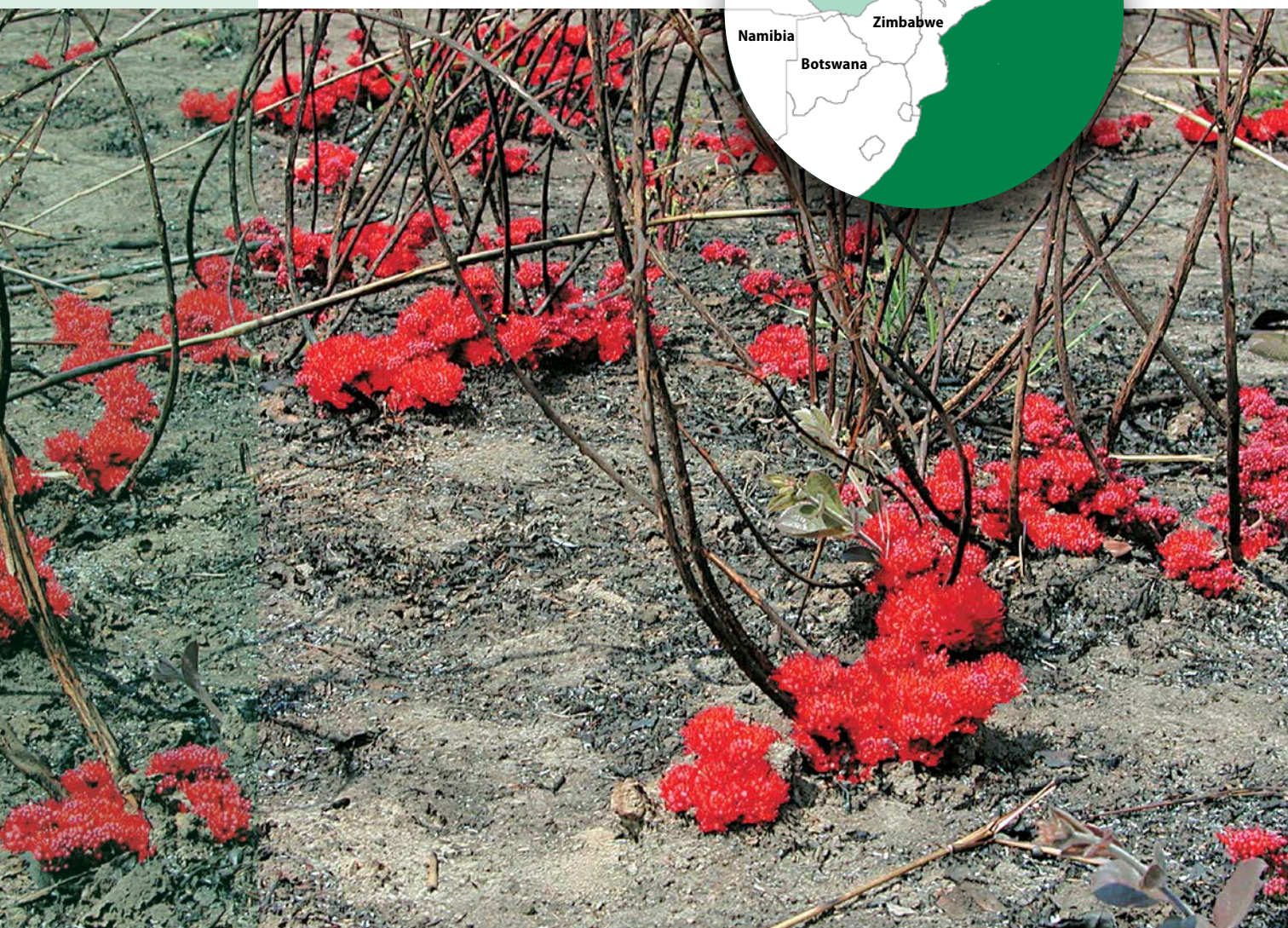
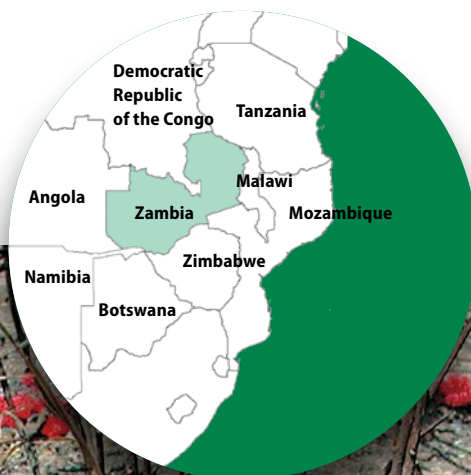


■ The outcome of the project had an indirect and positive influence on the behavior of local mining companies shown by the decision to shut down environmentally unsuitable operations and to modify existing smelters. One example is the closure of the smelter at Kitwe that was placing an unacceptable burden of contamination on the surrounding environment. Photo by B. Kříbek.

2008–2010

■ *Bulbostylis pseudoperennis*, an indicator plant of copper mineralizations, on the surface of an abandoned tailings pond near the city of Kitwe in the Copperbelt. Photo by J. Pašava.

The impact of mining and processing copper and cobalt ores on the Copperbelt Province of Zambia



This project carried out in Zambia and financed by the Grant Agency of the Czech Republic was focused on the investigation of the mineralogy and geochemistry of single sources of contamination (solid emissions from smelters, tailings stored in slime ponds, industrial waste waters drained from mineral processing plants) and on modelling the distribution of metals and sulphur in soils, sediments, waters and vegetation. The project was designed to define the types and sources of contamination entering soils and streams, and to determine the extent and degree of contamination in mining districts and to model the distribution and movements of contaminants in terrestrial and aquatic ecosystems.

The extent of contamination of soils and vegetation and of the crops cultivated in contaminated areas in the neighborhood of a former lead and zinc smelter in the Kabwe



■ Emissions of sulphur dioxide and dust fallout from smelters and dried-out flotation tailings ponds are the major sources of contamination of soils and vegetation in the Copperbelt Province. The area contaminated by sulphur dioxide and dust fallout exceeds 2,500 km². The topsoil down to a depth of 10 cm is most affected by contamination. Contamination of soils is indicated by the increase in the contents of various harmful elements in crops grown on contaminated ground. Photo by B. Kříbek.



■ The contents of metals and metalloids dissolved in the surface waters of the Copperbelt Province are particularly high in streams into which industrial waste waters from chemical ore processing plants are discharged. However, the main burden of contamination entering surface streams is due to the fine mineral particles suspended in waters escaping from flotation tailings ponds. Photo by B. Křibek.

region (Central Province of Zambia) was investigated. The possibilities of reducing the intake of toxic heavy metals by the root systems of economic crops were studied experimentally in this area. The composition of the chemical wastes in the Chambishi tailings pond and their effect on local streams in the Copperbelt Province were also studied. An investigation of the mineralogy and geochemistry of slags and dust fallout from the local smelter revealed that a significant fraction of the toxic elements are present in forms that are absorbed by the gastric system when ingested. The areal extent of contamination by dust fallout from smelter at Kitwe was studied using the isotopic composition of lead in soils and tree trunks. Specific attention was paid to the gastric accessibility of metals contained in soils, and in particular the degree to which individual metals are absorbed by the gastric lining. Sequential analysis was used to study the bonding of metals to individual components in the sediments and the proportion of metals in streams that are carried in form of true solution and physical suspension. The results of these environmental studies were presented at a number of international conferences and summarized in papers published in referred journals.

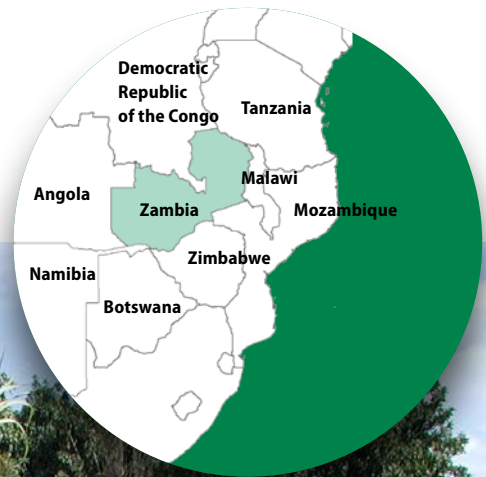


■ The contents of metals and metalloids dissolved in the surface waters of the Copperbelt Province are particularly high in streams into which industrial waste waters from chemical ore processing plants are discharged. However, the main burden of contamination entering surface streams is due to the fine mineral particles suspended in waters escaping from flotation tailings ponds. Photo by B. Kříbek.

2008

■ Sampling of cassava leaves and bulbs in the village of Chiseke, in an area highly contaminated by emissions from the Nkana smelter. Photo by J. Pašava.

Monitoring dust fallout from the smelter at Nkana and environmental education of high school students at Kitwe in Zambia



The project was designed to monitor dust fallout and sulphur dioxide emissions from the Nkana smelter in the city of Kitwe and was carried out in cooperation with students and teachers of high schools located near the smelter. Students from individual schools were trained in the methods used to collect samples of dust fallout and also how to use passive samplers for monitoring gaseous emissions so that they could participate directly in measuring and monitoring contamination in the field. Each school was equipped with an automated meteorological station for monitoring temperature, atmospheric precipitation and the direction and intensity of winds. Students and teachers also took part in seminars and workshops about the impacts of mining and mineral processing on the environment and human health and the benefits of modern



■ Seminars and discussions at three high schools were followed by an essay competition on the subject of the improvement of environmental conditions in the Copperbelt Province. Eleventh grade students from high schools in the cities of Nkana, Ndeke and Wusakile quarters of the city of Kitwe took part in the contest. Essays submitted by individual students were evaluated by a panel of teachers in cooperation with Dr. Bohdan Kříbek of the Czech Geological Survey and Professor Imasik Nyambe of the University of Zambia. The award ceremony for winners of the contest took place in the presence of representatives from the Czech Embassy in Harare and members of the School Board of Kitwe City Council. Photo by B. Kříbek.



environment-friendly technologies. A competition for the best essay on the subject of improving the environment in the Copperbelt was organized at three high schools following the seminars and relevant discussions.

The budget allocated to the project was mostly used to improve teaching aids in individual schools. A seminar devoted to the issue of air contamination in the environs of the local smelter was organized for representatives of mining companies and councillors from the city of Kitwe.

The new measurements of sulphur dioxide emissions showed that a significant reduction has occurred since measurements were made at single schools in 2005. This reduction was evidently due to the installation of desulphurization equipment at the Nkana smelter. However, the volume of dust fallout monitored near the smelter (at Mukuba, Nkana and Wusakile schools) is still very high when compared with the reference site at the Ndeke school corresponding to $3.2 \text{ g.m}^{-2}.\text{day}^{-1}$. For a short time, the total amount of suspended particles (TSP) in the atmosphere near the smelter exceeded the limits set by the World Health Organization. The dust in the environs of the smelter contains high amounts of Zn, Pb, Cu and Co, whereas the contents of Be, Cr, Mn, Ni, As, Mo and Cd are low. This indicates that the local copper and cobalt smelter is responsible for the dust fallout in this area. High concentrations of lead and zinc in dust particles are due to the volatility of these metals during the smelting process. The results of the environmental monitoring programme were submitted to co-workers from the University of Zambia, to the individual schools that participated in the programme and to the Kitwe City Council. The evidence provided by these measurements gave support to public opinion, resulting in the closure of the old metallurgical plants and the construction of a modern environment-friendly metallurgical complex.

■ << Sampling of contaminated soil in the environs of the Nkana smelter.
Photo by B. Křibek.

■ Teachers and students from local high schools were involved in monitoring dust fallout. Photo by B. Křibek.

■ >> Project results were handed over to Mr. P. M. Chanda, secretary of the Ministry of Mines and Minerals Development of Zambia. Photo by B. Křibek.





Crushed ore is washed in primitive sluice boxes. Defects in the sluice boxes such as the wrong inclination and irregular water flow, etc. result in poor recovery of gold during gravitational separation. The photograph shows gravitational procedures used for the recovery of gold at Pousghin. Photo by J. Pašava.

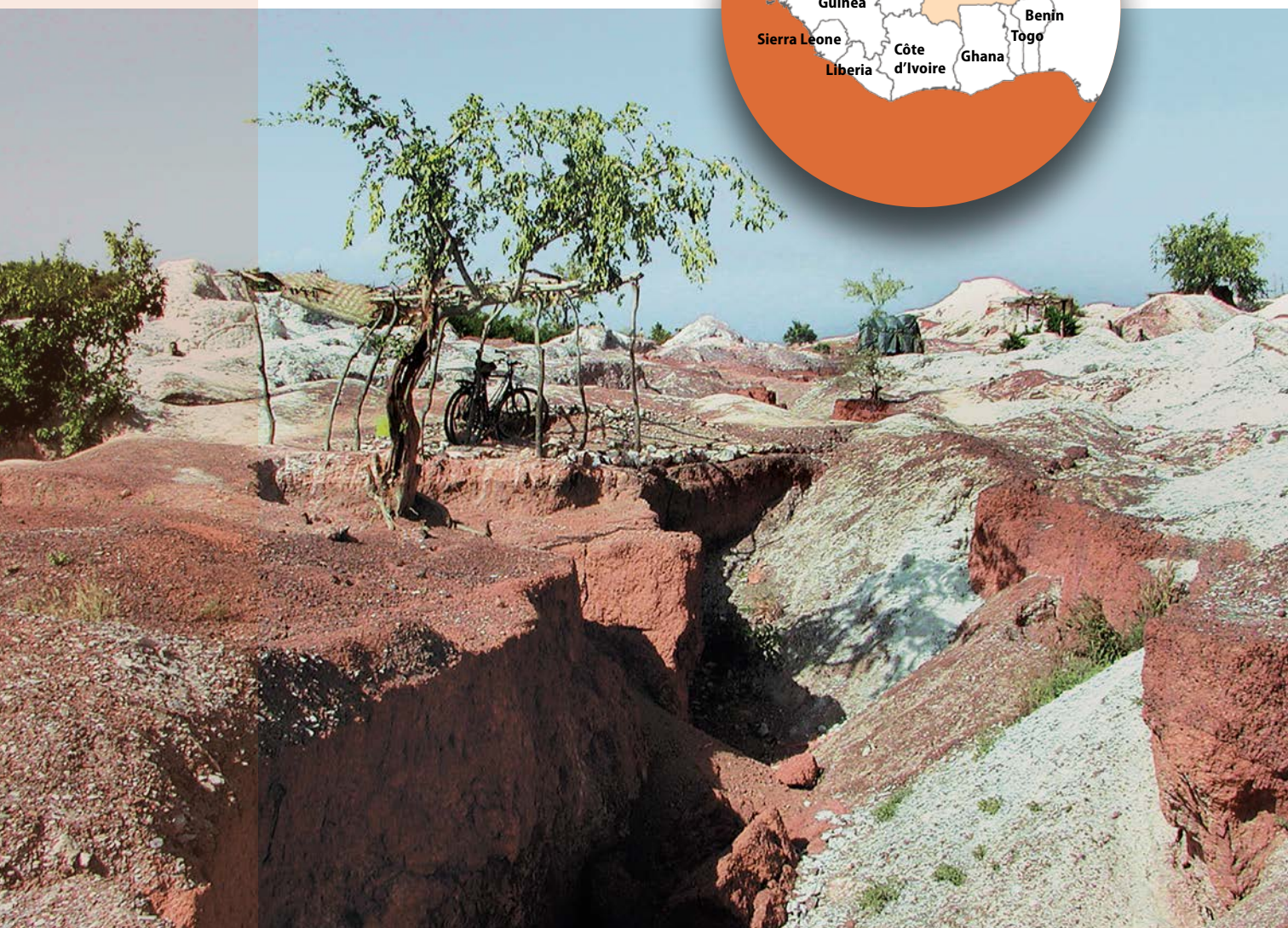
MINERALS

Mineral exploration and safeguarding of mineral resources, particularly the evaluation of potential deposits, including secondary sources of minerals in waste from indigenous mining, have been the focus of projects conducted by Czech economic geologists, geochemists and other specialists in many places around the world. Economic geology projects are one of our most important foreign activities, because the discovery and rational use of raw material resources are in some countries one of the few ways of increasing the standard of living of the local population.

2003–2005

■ Uncontrolled artisanal mining of gold-bearing quartz veins often leaves behind open and extremely dangerous pits, locally up to 50 m deep. Photo by J. Pašava.

Assessment of gold resources in tailings left after artisanal mining in Burkina Faso



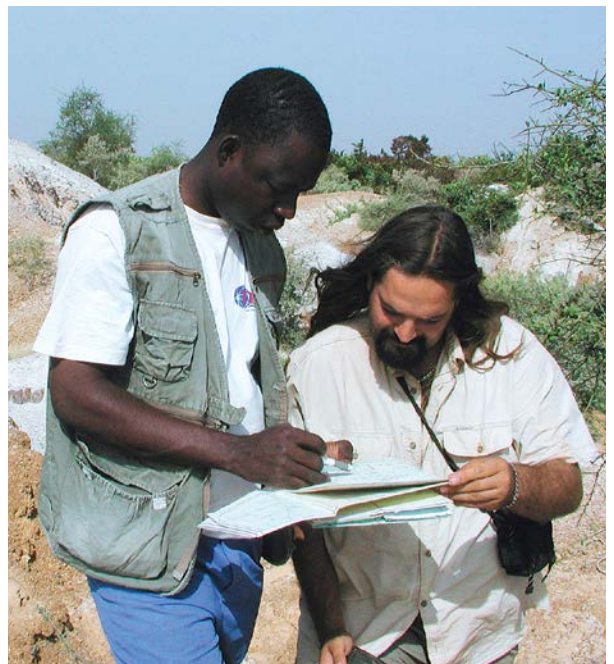
This project was designed to assess the secondary resources of gold remaining in tailings left after artisanal mining and mineral processing operations in Burkina Faso and to study the feasibility of future exploitation. The aim was to contribute to industrial development through sustainable exploitation of mineral resources and to improve the living standard of the local population in selected regions where artisanal gold mining and processing is the economic mainstay. The project was carried out by the Czech Geological Survey in cooperation with the Burkina Faso Geological Survey (BUMIGEB) and the Czech Explomine Company Ltd based in Jihlava. The work was carried out under the auspices of the Cooperative Development Programme of the Government of the Czech Republic.



■ The results of the project were presented at a concluding seminar attended by a large audience including representatives from the Burkina Faso central administration, local miners, representatives of the national media as well as representatives from the Ministry of Environment of the Czech Republic. Representatives of the Ministry of Mines and Energy and members of the Association of Artisanal Miners showed their appreciation of the project outputs, particularly those that can be applied immediately in small-scale mining operations and also used for training local miners in practical procedures. Photo by E. Komínek.

■ > Women make up the majority of gold prospectors at the Dio deposit in the Yatenga Province, where gold is recovered from lateritic residues. Photo by J. Pašava. Photo by J. Pašava.

■ > Joint teams of Czech and Burkina Faso geologists worked in a number of regions of Burkina Faso. Photo by J. Pašava.





Field studies were undertaken at a total of 63 artisanal gold mining operations in three regions of Burkina Faso. The results demonstrate that the tailings remaining after mining in northern regions of the country are poorer in gold and more coarse-grained relative to localities in the south.

A rational estimate of gold resources contained in tailings left after artisanal mining and mineral processing was based on the models of distribution obtained from each of the localities and the size of the individual deposits distributed over an area of 5,591 km² in the Yatenga region of northern Burkina Faso. For the purpose of this calculation, the results of the project undertaken during 2003–2005 were also taken into account. It is calculated that a total of 24 tonnes of gold are contained in 18 M tonnes of mine waste, and that ca 5.1 tonnes Au are contained in 0.7 M tonnes of tailings left after mining and processing of primary gold ores. In addition there are ca 2 tonnes of gold contained in 20 M tonnes of tailings produced as a result of mining and processing of lateritic residues. Altogether it was calculated that an estimated total of 30.5 tonnes of Au is contained in the spoil produced by gold mining in Burkina Faso.

The waste products from the mining of primary gold ores are considered to be the most promising for commercial extraction. The efficiency of about 75% of these operations could be improved by introducing better methods of artisanal mining; only 5% are suitable for small- or medium-scale mechanized mining. These are deposits with gold reserves in excess of 100–200 kg gold. The majority of sites with tailings are also suitable for medium-scale mechanized mining because of the relatively high contents of very fine-grained and chemically bound gold (4–5 g/t) that can be extracted by cyanide leaching.

The most environmentally dangerous practice in all the artisanal operations is the use of mercury for amalgamation and trapping of fine gold. This is illegal but its use continues to be widespread in all artisanal operations. The result is serious contamination of the soil and groundwater as well as systemic poisoning of those who use it. Ca 1 g of mercury is needed for the extraction of 1 g of gold. During roasting of the amalgam the mercury escapes into the atmosphere. In contrast to other well-known contaminants (e.g. cyanide) used in the extraction of gold, mercury persists as a toxic element in the environment for an indefinite time and inhalation of the vapour rapidly leads to chronic poisoning and damage to the human nervous system (hydrargillism).

The continuation of the project has been guaranteed by training representatives from the authorities in Burkina Faso in low cost procedures for the extraction of gold from these residual artisanal resources.

■ << Dry blowing (*vannage* in French) is used to recover gold from lateritic residues at the Namissiguima deposit, Yatenga Province, northwestern Burkina Faso. Photo by J. Pašava.

2010–2013

■ Geochemical and mineralogical studies aimed at defining areas with high mineral potential in West Africa were carried out in close cooperation with mining companies. Photo by B. Křibek.

Tectonic development and the prediction of mineral potential in West Africa



In 2010, the Czech Geological Survey became one of the co-investigators in the “West African Exploration Initiative”. This project was designed to create a new tectonic model for the structure of West Africa paying special attention to the regional structures that control the origin and location of mineral deposits. The intention is to provide improved criteria for the evaluation of the mineral potential of West Africa.

In the context of this project, the Czech Geological Survey is carrying out an investigation of the factors governing the distribution of gold and other metals in primary and secondary geochemical aureoles of ore deposits in Burkina Faso, Mali, Senegal and Ghana. In Burkina Faso, soils, gossanous laterites and regolith were sampled during the first stage of the project. Samples were analyzed in the field using



■ Gold concentrate obtained from tailings at the Boutouonou 3 mining operation in eastern Burkina Faso using gravitational methods. Photo by J. Pašava.



a portable XRF analyzer and then in the laboratory using the ICP-MS method (mass spectrometry). The composition of clay minerals and changes in the pH values of aqueous leachates from mineral aggregates collected from individual sections of the weathering profiles were also studied.

The results obtained in 2010 showed that the geochemical properties of the soils are governed to a large extent by the composition of the underlying rocks. From the point of view of geochemical exploration, the most significant elements associated with gold in the solid products of weathering are As and Cu. The relatively low mobility of both elements during weathering processes is probably controlled by their adsorption on ferric oxides (hematite, goethite) originating from the weathering of minerals containing iron in the ferrous state.

■ << Primitive gold mining in the Kongoussi Department in northern Burkina Faso. Photo by J. Pašava.



■ Education and training of local specialists at seminars and workshops and during field excursions are an integral part of the project. Special attention is paid to the application of modern geochemical, geophysical and structural methods of investigation. Photo by B. Kříbek.

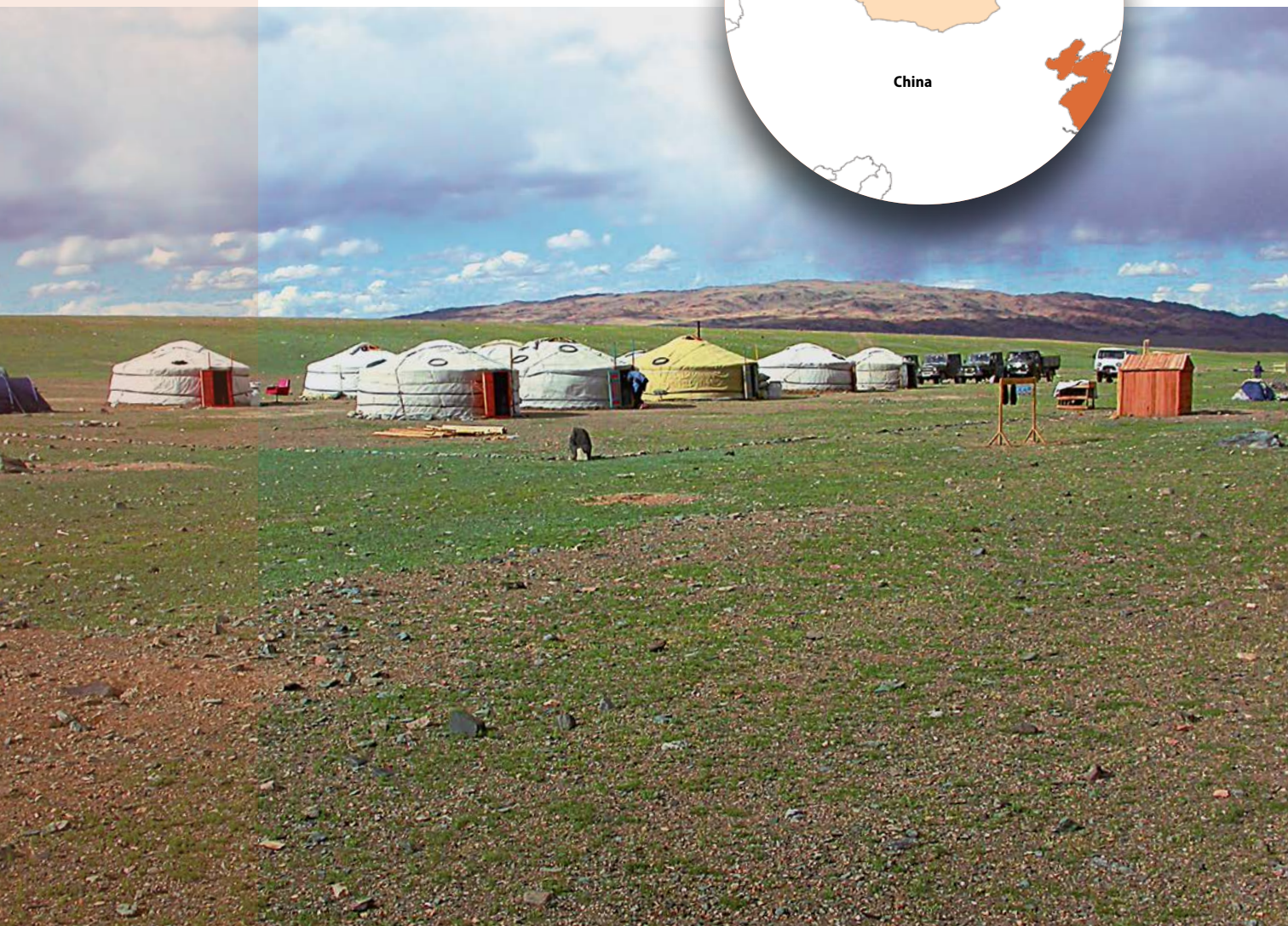


■ Sampling and geochemical analysis of soil from two separate horizons in the weathering profile is used in the search for mineral deposits in order to distinguish anomalies due to surface contamination from those due to primary or secondary mineralization. Photo by B. Kříbek.

2003–2007

■ Camp of the geological expedition in 2005, with the sacred mountain Chandman Khayrkhan Uul (elevation 2,802 m) in the background. Photo by P. Hanžl.

Geological mapping in the Mongolian Altai



Mongolia is a country of endless horizons, steppes and deserts and also of vast mineral wealth that has attracted geologists and prospectors from all over the world. The mineral resources of this landlocked country will supply the revenue on which the future improvement of the standard of living of the population depends. Because systematic exploration for mineral deposits should start from high quality geological maps, the Mongolian government places a high priority on geological mapping. In this context, the aim of the CGS project was to compile geological, hydrogeological and geochemical maps covering the area of the border between the Mongolian Altai and the Gobi Altai mountain ranges, placing emphasis on the assessment of the mineral resources of this region.



■ The programme of geological mapping was carried out in close cooperation with Mongolian geologists. Because of the varied geology and topography of the area, it was suitable for training Mongolian geologists and students in the use of modern methods of geological mapping and procedures used for processing and interpreting of geological and other relevant data. Photo by P. Hanžl.



■ A small gold mining operation recently opened at one of the localities proposed for follow-up exploration proves the value of undertaking geological mapping and exploration geochemistry in the region. Gold nuggets a few tens of grams in weight were discovered in this placer gold deposit. Photo by P. Hanžl.

Preliminary work began in 2003 and field work was carried out during the summer seasons of 2004–2006. A Final Report was submitted to the Mongolian Department for Oil and Mineral Resources in May 2007. Altogether 87 maps at 1:50,000 and 1:100,000 scales covering an area of almost 4,000 km² were compiled.

Much of a large amount of acquired data was new in terms of the areas investigated and the spectrum of topics covered. The data include primary geological observations, together with geophysical measurements made in the field and petrographic descriptions, mineralogical and geochemical analyses and radiometric dating made in the laboratory. These results are being used in hydrogeological, sedimentological, and geophysical interpretations useful for mineral exploration, and other practical purposes. An important output of the project is the information system in which all the data were systematically compiled so that geological and structural interpretations could be made and areas of interest for water and mineral resources could be delineated.

A range of outstanding geological exposures providing new information about the geological structure, mineralogy and palaeontology of the region were discovered and recorded during geological mapping.

Hydrogeological mapping and investigations carried out in areas previously believed to contain little water led to the discovery of new resources. Information about the topographic coordinates and the physical and chemical parameters of the water in these new areas were fully recorded.

A range of geochemical anomalies were identified and a few promising occurrences of Au, Cu and As-Sb-Hg mineralization were detected in the field in the course of geochemical mapping in which emphasis was placed on surveys of heavy minerals and stream sediments. Promising accumulations of some industrial rocks and minerals, in particular pure limestones, gravels and sands, were identified in the area.



■ The geology of the northern part of the area is formed by the Neoproterozoic to Lower Palaeozoic complexes of the Lake zone, whereas the southern part lies in the area of consolidated Variscan rocks forming the Gobi Altai. Photo by P. Hanžl.

2008–2012

■ Steppe in the Altai foothills in the territory of Uvs Aimag in northwestern Mongolia, enlivened by a pair of brown vultures with a wingspan of nearly 3 metres. Photo by P. Mixa.

Assessment of exploration licences granted by the Mongolian government



In 2008–2012, at the request of a private investor, the Czech Geological Survey conducted expert assessments of 22 selected exploration licenses with Fe-Mn, Cu-Mo, Au and Pb-Zn mineralization in the aymags (an administrative unit corresponding to region) of Uvs, Dzavhan and Hovsgol in the northern and northwestern parts of Mongolia. As a result of the field reconnaissance, five of these were judged to be unprospective and it was recommended that the licenses be surrendered. One exploration licence with Cu mineralization, possibly of porphyry copper type, was assessed as very promising and a follow-up programme of exploration was proposed. Other localities require further investigation before proposals for a programme of mineral exploration and/or a feasibility study can be made.

■ Collecting heavy mineral samples to determine the content of heavy minerals, primarily gold and copper minerals. Photo by P. Mixa.





■ An exploration license located near the town of Ulaangom in northwestern Mongolia. The picturesque landscape is formed by a large pluton of two-mica granite with a deep red colour intruded by a greisenized stock ca 60×250 m in size (in the foreground of the picture). This rock consists of quartz, white mica, topaz, magnetite and pyrite. Locally, molybdenite and secondary copper minerals were also found. Photo by P. Mixa.



■ Observation and description of a fracture zone in the Khan Khukhiyn Nuruu mountain range in the northwestern part of Mongolia. The structure is 2 m wide and a few hundreds of metres long and contains crushed quartz gangue accompanied by chalcedony. Chemical analysis of samples showed low concentrations gold up to a maximum of 4 mg per tonne. This is not economically workable. Photo by P. Mixa.



■ Newly discovered showings of copper mineralization in the aymak of Muron near the Sangiyn Dalay Nuur Lake. Chalcopyrite is the major mineral accompanied by minor cuprite, bornite and secondary malachite. Photo by A. Seifert.

2009

■ The main field base of the Engui Tal Company that was granted a mining licence for extraction of gold at Ongon Ulaan Uul. Photo by A. Seifert.

Mineral deposit of gold and platinum at Ongon Ulaan Uul in the southern Gobi



In 2009, a team from the Czech Geological Survey examined the Ongon Ulaan Uul mineral deposit and compiled an expert report on the possibility of establishing a Czech-Mongolian joint venture to mine placer gold. Earlier mineral exploration work proved the existence of 300 kg of gold in the C1 and C2 resource categories. The gold particles contain 5% of silver and their shape indicates that they have only been transported a short distance from the primary source. Placer gold is accompanied by platinum minerals among which native platinum and iridosmine prevail.

In the southeastern part of the area a new locality was discovered in the flood sediments of an enclosed basin that is prospective for workable accumulations of gold and PGMs. The central part of the area is underlain by granites, dacites and

■ Exploratory percussion drilling of productive basal gravels and sands. The drill core is then evaluated by panning. Photo by A. Seifert.



rhyolites and also shows a favourable pattern of structures, extensive hydrothermal alteration and zones containing enhanced concentrations of copper, gold and locally even molybdenum. These may be indicative of underlying mineralization of porphyry copper style (Cu-Mo-Au).

2013–2016

■ Geological mapping in the western Mongolian Altai north of Somon Munkhkhairkhan. The mountain range consists of folded sediments with abundant granite plutons. Photo by V. Žáček.

Geological mapping at 1:50,000 scale and evaluation of the economic potential of a selected region of western Mongolia



The project, abbreviated as “Mongol Altai-50”, included geological mapping at a scale of 1:50,000, geochemical prospecting and an evaluation of all types of mineral deposits. The project also included field training for young Mongolian geologists and geology students involving all methods of work that was carried out in an area of 1,770 km² located in the western Mongolian Altai in the Munkhkhairkhan, Mankhan and Zereg sumd (districts) in the Khovd Aimag (province).

The project was carried out in 2013–2016 and involved the collaboration of 32 experts from four countries along with 40 other co-workers, such as technicians, drivers and assistants. During the project, 2,832 documentation points were processed, five basic geological maps at a scale of 1:50,000 and 60 geochemical anomaly maps were

■ The team of the Czech-Mongolian expedition “Mongol Altai-50” in the base camp at the confluence of the rivers Dund Tsenkher Gol and Uliastayn Gol in the western Mongolian Altai. Photo by V. Žáček.



compiled, and maps of the mineral potential of the surveyed area were constructed. CGS specialists trained 19 young Mongolian geologists and students during the course of the project. The final report was successfully reviewed in Ulaanbaatar in October 2016. Many of the project’s results were later published in reputable journals.

2005–2007

■ Afghan geologists discussing the geological structure of the dark grey marble at Gazag. This locality lies ca 45 km east of Kabul. Individual marble beds are 0.7–1.8 m thick. Photo by I. Knésl.

Assistance in redevelopment of geological institutions and organizations in Afghanistan



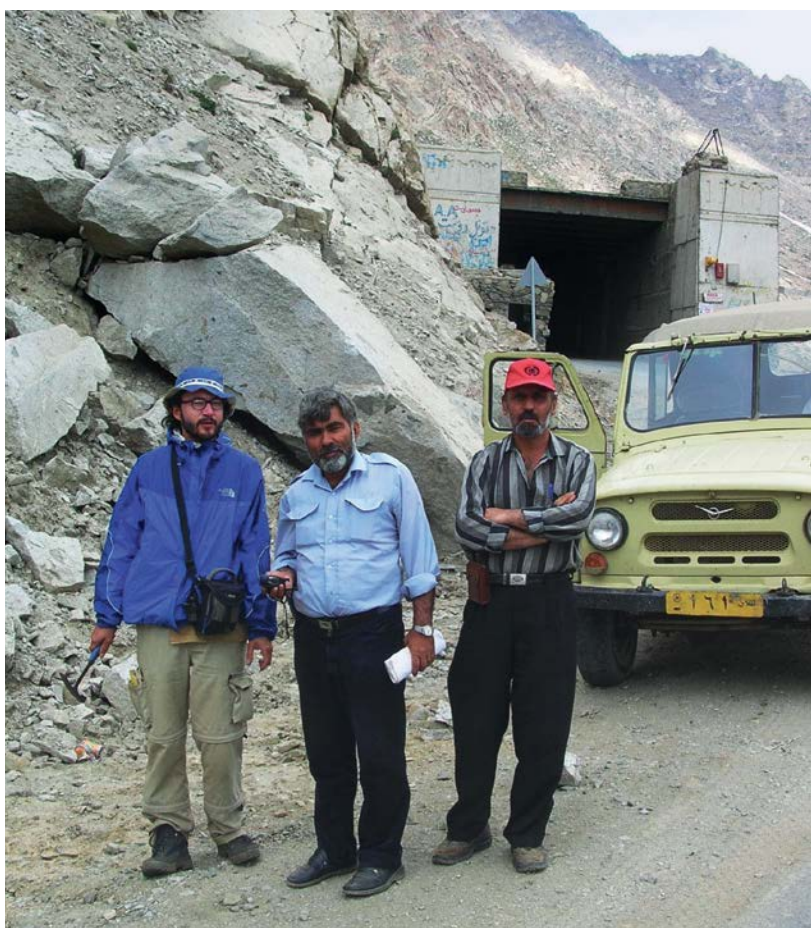
From 2005 to 2007, the Czech Geological Survey participated in a Cooperative Development Programme with Afghanistan aimed at reviving the geological institutions in the country, placing specific emphasis on the systematic development of mineral resources in the country. The Company GET Ltd, in liaison with the Faculty of Science of Charles University, was responsible for the Czech side of the programme, while the Afghan counterpart organizations were the Geological Survey of Afghanistan and the Faculty of Geological Sciences of Kabul University.

The programme consisted of educational and field reconnaissance projects which were run in parallel. The educational part consisted of training courses, classes and lectures covering petrology, structural geology and remote sensing.



■ Visit to the chemical laboratory at the cement factory in Jabal Seray. The first person on the right is Dipl. Eng. Islamuddin Ahmadi, the director of the cement factory, next to him is Dipl. Eng. Abdul Wasay. This laboratory, like many others in Afghanistan, is operated using only very basic equipment. Photo by I. Knésl.

■ > A brief stop to examine the granite outcrop in the valley of the River Salang ca 5 km downstream from the Salang tunnel. Concrete barriers for protection against falling rocks can be seen behind the jeep. Photo by I. Knésl.





These were organized at the universities in Kabul. The ultimate aim was to enable the Afghan geological community to develop rational procedures for the integrated and sustainable exploration and development of mineral resources. Modern methods of mineral exploration were tested in the field by geologists from the Geological Survey of Afghanistan assisted and supervised by the Czech team.

In 2005, fieldwork was carried out to assess the resources of ornamental marble at Cheste Sharif in Herat Province and of gypsum for the cement industry at Suah Ab. Chemical analyses of the raw materials were made and the marbles were subjected to mechanical tests to determine their strength and other physical properties. In 2006, field work was carried out in two other areas. One was the Callaw lignite deposit in Kabul Province and the other was in Parvan Province where raw materials for the production of cement occur. The work in Parvan Province continued for a further year and the deposit of black (blue-grey) marble at Gazag was also investigated.

■ << Inspection of an abandoned quarry, located north of the cement factory in the town of Jabal Seray. Its reserves that were used for cement production have been exhausted. Photo by I. Knésl.



■ Cement factory at Jabal Seray. The small town of Jabal Seray lies in Parvan Province the administrative centre of which is the town of Charikar. The cement factory was constructed during the 1950s by Czechoslovak experts as part of a programme of economic aid to friendly countries. Photo by I. Knésl.

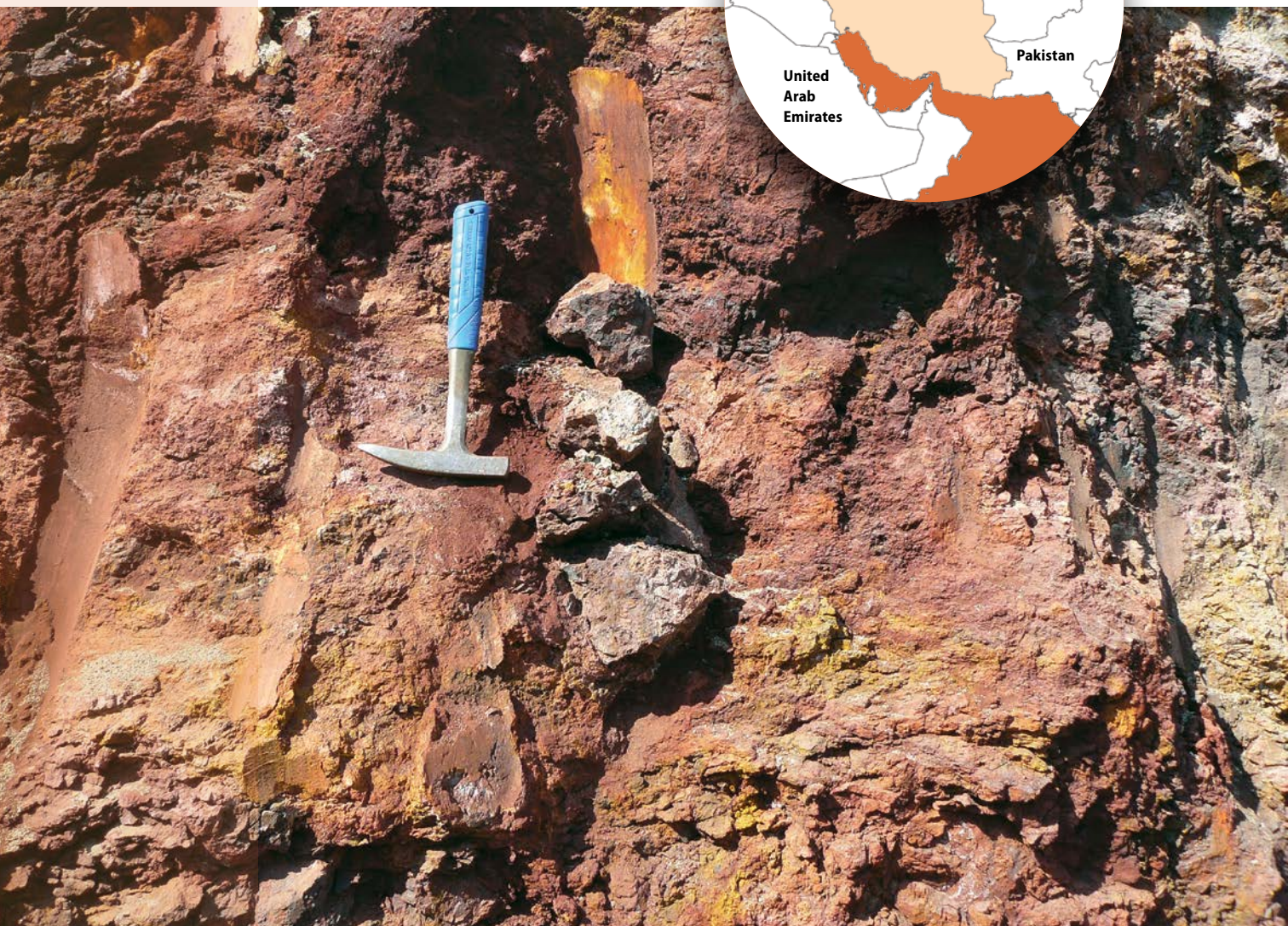
■ Tour of the cement factory at Jabal Seray. During the visit, the cement factory was not in operation because of the lack of raw materials for cement production. The only working part of the complex was the crushing plant where aggregate is produced for the repair of damaged roads. Photo by I. Knésl.



2010–2012

■ The Fe Esmalun deposit consists of an up to 20 m thick gossan, dominated by hematite, with magnetite. Secondary Cu mineralization comprising malachite and azurite is evident in the oxidation zone. Photo by P. Mixa.

Assessment of potential iron and manganese ore deposits in Iran



At the request of a private investor, the Czech Geological Survey carried out an expert evaluation of selected iron and manganese ore deposits in the Kerman Province and in the areas of Shiraz and Bandar Abbas in the central part of Iran in 2010–2012. A total of 19 sites with prevailing magnetite and hematite mineralizations of varied origin, shape and structural-tectonic position were inspected and evaluated. Three other licenses with occurrences of Fe ores, located southwest of the city of Sirjan in the Gol-el-Gohar

■ Turkam is a recently developed hematite deposit located along the road connecting the cities of Yazd and Neyriz. The E–W oriented ore deposit is underlain by chlorite-sericite phyllonites (chlorite-seric shales) and overlain by quartzites and quartzite gneisses. The ore body has a steep dip of 45–85° and a true thickness of 10–12 m. Mining is intermittent depending on demand. Photo by P. Mixa.





■ Typical semi-desert landscape of the southern part of Iran in the Fars Province, near the city of Neyriz – view of the northern foothills of the Zagros Mts. Numerous smaller deposits of hydrothermal manganese ores associated with cataclastic zones, developed in the volcano-sedimentary formation of Upper Cretaceous age, occur in the area. Photo by P. Mixa.

ore district in the vicinity of the largest state-owned mines, were recommended for follow-up assessment.

The most important iron ore deposits in Iran are of the hydrothermal metasomatic and skarn type, locally with associated apatite, which are hosted by Late Proterozoic to Palaeozoic volcano-sedimentary and metamorphic formations, commonly with superimposed alkaline intrusions. The largest deposits mined by state-owned companies are horizontal ore deposits and lenses several metres to several tens of metres thick containing roughly 45% magnetite on average. The overburden thickness ranges between 50 and 250 m. The ore reserves in these deposits amount to approximately tens of millions of tonnes.



■ An insignificant magnetite layer, mined locally in the past, was documented in the Ghuri exploration license, west of the city of Sirjan in southern Iran. Magnetite forms thin, partially remobilized layers tens of cm to 2 m thick in ochre-coloured crystalline limestones. The layers are sub-economic. Photo by A. Seifert.

2007–2009

■ View of the huge open pit at the Kalmakyr deposit from which Cu-Au (Mo) ores of porphyry type are extracted. Photo by J. Pašava.

Investigation of platinum group elements (PGE) in the gold and copper deposits of Uzbekistan



Financial support for a joint project between the Czech Geological Survey and the National University of Uzbekistan was granted by the Ministry of Education, Youth and Sport of the Czech Republic as part of the KONTAKT programme.

The project was designed to study the sources, transport and fractionation of platinum group elements in the gigantic gold and copper deposits of Uzbekistan. The first field reconnaissance of epithermal Au-Ag deposits at Kyzylalma, Kochbulak and Chumauk I and of the porphyry copper deposit at Kalmakyr containing gold and molybdenum was undertaken in 2007. The second stage of fieldwork, during which

■ Collecting samples of Cu-Au (Mo) mineralization in the Kalmakyr porphyry copper deposit. Photo by J. Pašava.



■ Ore being transported from the portal of the epithermal Au-Ag deposit at Chumauk I. Photo by J. Pašava.





■ Landslides are often visible around the Au-Ag deposit at Kochbulak that is hosted by andesitic and dacitic volcanic and pyroclastic rocks. Photo by J. Pašava.

samples were collected from orogenic gold deposits at Amantaytau, Daugystau, Vysokovoltnoye and Myutenbai and from gold deposits hosted by the intrusions at Charmitan and Guzhumsai was carried out in 2008.

The highest contents of Pd (292 ppb) were found in samples from the Kalmakyr (Cu-Au) porphyry copper deposit. Palladium shows a positive correlation with Cu and Ag and appears to be distributed in chalcopyrite and tetrahedrite.

The rhenium-osmium dating of black shales from a drill hole in the Muruntau-Myutenbai ore district indicates a Neoproterozoic age of 697 ± 20 Ma for the Besapan suite that lies in the central part of the Kyzylkum region in western Uzbekistan. These rocks host many of the largest gold deposits in the Kyzylkum. Modern isotopic methods of age determination are enabling coherent interpretations of the metallogensis of this productive belt.



■ View of the medium- to low-temperature Au-Ag mineralization exposed in the open pit at Kochbulak. The mineralization in the face is hosted by andesites and dacites. Photo by J. Pašava.

2007–2009

■ Collecting chromite ore samples from the Centralnoye I deposit. Photo by J. Pašava.

Investigation of the distribution of platinum group elements (PGE) in the Polar Urals



In 2007, the Ministry of Education, Youth and Sports of the Czech Republic granted financial support for a joint project with VSEGEI (All-Russian Research Institute of A.P. Karpinsky) as part of the KONTAKT programme. The project was designed to study the distribution of platinum group elements in various geological units of the Polar Urals.

During 2007, field reconnaissance and sampling were carried out at the following deposits: Centralnoye – Cr ores, Sophronovskoye – P ores, Khaberskoye – Mo ores and Ozernoye – Cu ores.

Analyses of the different samples showed that the highest concentrations of platinum group elements occur in chromium ores from the Centralnoye I deposit and enhanced concentrations were found in Cu ores of the Ozernoye deposit. A decision



■ Massive chromite ores hosted by dunites at the Centralnoye I deposit contain anomalous concentrations of platinum-group metals. Photo by J. Pašava.

■ Discussions with local geologists in the Polyarnoye field camp were an essential part of the project. Photo by J. Pašava.





was made to carry out detailed studies of the mineralogy and geochemistry of the Cr ores from the Centralnoye deposit.

The results showed that the chromium ores of the Centralnoye I deposit are enriched in elements of the Ir subgroup, but on average contain lower amounts of Ir, Pt, Pd, Ru, Rh and Au compared to ores in the neighbouring Centralnoye II deposit. The higher average content of Au in the Cr ores of Centralnoye I deposit as compared to the Centralnoye II deposit indicates the presence of native gold. Because the average concentration of PGE in the chromites from Centralnoye I (Σ PGE = 126 ppb) is relatively high and the reserve of PGE is estimated to be ca 0.6 tonne, this deposit is considered to have the potential for commercial extraction of platinoids.

■ << Typical landscape in the area of the Ray-Iz Massif in the Polar Urals. Photo by J. Pašava.



■ A tent and a three-wheel vehicle adapted to arctic terrain are essential equipment for field geologists working in the Polar Urals. Photo by J. Pašava.



Participants in the GEOCHIM/UNESCO course during practical training in heavy mineral survey methods.
Photo by J. Pašava.

EDUCATION

In recent years, the Czech Geological Survey has provided numerous training courses for foreign geologists around the world, either as part of the International Development Cooperation of the Czech Republic or as part of commercial projects or other CGS activities.

We consider the transfer of knowledge and experience an integral part of our foreign mission.

2006–2010

■ Landscape northwest of Kharvana. The massif of the igneous rock complex of Siahrud is separated from Cretaceous marine sediments by a tectonically predisposed valley. Photo by J. Babůrek.

Training of geologists from the Geological Survey of Iran in geological mapping at a scale of 1:25,000



Training of Iranian geologists in mapping and compilation of geological base maps at 1:25,000 scale consisted of courses and lectures in a range of geological and related disciplines such as basic methods of geological mapping, mineral exploration, exploration geochemistry, environmental-geochemical mapping and identification of geohazards. In addition, two-day workshops were devoted to special methods in hydrogeology, Quaternary desert geology, the use of electron probe microanalysis in mineralogical studies and the application of micro-chemical tests to identify minerals in the field. Some information about the turbulent history of the Czech Republic was included in the courses to provide relief from the technical aspects of geological



■ Geological mapping and field observations of the Hajilar Chay fault zone at the village of Tilkari. The River Hajilar Chay is an important source of water in this relatively dry region. Even rice is cultivated in some places along the river valley but otherwise the major agricultural activity in this region is pastoral. Photo by J. Babůrek.

■ The hilly Ordobad Massif covers most of the area of the Avan and Eshtobin maps sheets. It consists mostly of monzonites but a new gabbro body was identified in the eastern part of the massif. Radiometric dating was used in this area for the first time and showed that the gabbros are of Middle Eocene age and are thus the oldest intrusive rocks so far known in the massif. In the field, Iranian colleagues were trained to distinguish the different facies of intrusive rocks forming the Ordobad Massif. Photo by R. Vodrážka.





■ Exploration for mineral deposits was one of the main tasks of the educational and training programme. Copper is obviously the most important raw material that is now mined in the wider region around the area of interest. In addition to the Sungun deposit mentioned above, there are some other smaller deposits in the area that were mined in the past. Private investors (e.g., Mazrae Mazareh) plan to develop or re-develop some of these deposits. A large copper deposit has been mined at Megri in Armenia, not far from the Iranian border. One of the important indicators of this kind of mineralization is the occurrence of secondary copper minerals on outcrops that are characteristic of strikingly green (malachite) or blue (azurite) colours. Photo by D. Mašek.

mapping and mineral exploration and enable the Czech and Iranian geologists to find common ground in their two cultures.

As a result of cooperative field and laboratory investigations, four geological map sheets with four environmental-geochemical surveys (consisting of ca 50 thematic maps depicting geochemical anomalies of individual elements), eight mineral deposit maps and four maps of geohazards were compiled by the Czech and Iranian teams. The Czech Geological Survey supplied a large quantity of analytical data including new radiometric dating beyond the scope of the original project.



■ Czech geologists discovered a unique natural phenomenon at the village of Chervik near the town of Ghalandar. An outcrop was found in which the Pleistocene loess was covered by a lava flow. This sequence proved that Quaternary to sub-Recent volcanism took place in the area surveyed. Photo by J. Otava.

2013–2015

■ Field training involving documentation of rock outcrops. Photo by V. Rapprich.

Improving the quality of higher education in Earth sciences, particularly in combating geohazards in Ethiopia



The cooperation with the Geological Survey of Ethiopia (GSE) demonstrated the need for greater preparedness of graduates of Ethiopian universities in the multidisciplinary field of environmental geology. Therefore, a project aimed at improving the effectiveness of teaching and education at Addis Ababa University and Arba Minch University was launched in 2013. In the case of Addis Ababa University, the training focused mainly on hydrogeology and was conducted by the staff of the Aquatest Company. By contrast, the training at Arba Minch University included various disciplines used in geohazard research, which mainly included physical volcanology, rock and environmental geochemistry, tectonics, palaeoseismology and applied geophysics.



■ Practical field-based environmental geochemistry course with students from Arba Minch University. Photo by V. Rapprich.



Theoretical instruction was combined with practical field training at both universities. Each course at Addis Ababa University was attended by 15–20 master’s and doctoral students specializing in hydrogeology. Approximately 45 bachelor’s students took part in each course at Arba Minch University. In addition to the transfer of knowledge to students, teachers were also acquainted with modern teaching methods, which engage students to a greater extent and develop initiative. The project included the handover of field equipment and selected specialized literature. The GSE was also significantly involved in organizing the courses because it is an institution that can employ future graduates and benefit from their knowledge.

■ << Vernacular architecture in front of volcanic cones in southern Ethiopia. Photo by V. Rapprich.



■ A group of students of Arba Minch University during a volcanology field course. Photo by V. Rapprich.

■ Practicing field documentation of geological exposures with students from Arba Minch University. Photo by V. Rapprich.

2017–2019

■ Participants of the PanAfGeo mapping course on a geological excursion to a quarry near Axum, where phonolite blocks for stelae are located, which have been preserved here for 2,000 years. Photo by V. Štědrá.

PanAfGeo: Increasing geoscience knowledge and skills in African geological surveys



A joint training project of the Organisation of African Geological Surveys and 12 EuroGeoSurvey members, which is funded by DG DEVCO EC, was launched in 2017 to support the activities of African geological surveys. Within three years, nearly 1,500 staffmembers of African organizations will be provided with knowledge and skills through seven thematic work packages to develop their professional expertise. As part of the challenging principal “Work Package 1”, the CGS team provides and coordinates training courses on basic field mapping via six-month field courses, including a transfer of essential theoretical knowledge.

The introductory block in 2017 included a 10-day training session involving “remote sensing in geoscientific mapping” in Ethiopia, which was attended by



■ Transfer of field data to a map and preparing the group for the next day (Axum). Photo by V. Štědrá.

■ > One of the working groups conducting mapping activities in a belt of dolomitic limestone near Adwa. Photo by V. Štědrá.

■ > Expert team of the first field course in Ethiopia, composed of experts from the Czech and Ethiopian geological surveys. Photo by V. Štědrá.





25 representatives of 13 African countries. The first in a series of demanding field mapping courses followed in early 2018 in Axum in northern Ethiopia, in an ideally exposed and geologically varied mountainous area of the Tigray Region. This course was provided in English and attended by other representatives of 13 African geological surveys. In addition to a team from the Czech Geological Survey, specialists from the Geological Survey of Ethiopia and experts from the Mekelle and Addis Ababa universities were professionally engaged in the course as well.

Two follow-up field courses are being prepared, one course in English in Central Namibia and one course in French – with the participation of BRGM geologists – in and around Agadir, Morocco. The mapping courses in the third year of the PanAfGeo project are expected to be repeated again in Ethiopia, Namibia and in Francophone Senegal.

■ << The surface of Neoproterozoic dolomitic limestones shaped by dissolution forming karren. Adwa, northern Ethiopia. Photo by V. Štědrá.



■ African geologists are acquainted with field experience and methods by the CGS team at outcrops of travertine (left), granite (right) and limestone (bottom) near Adwa and observed with considerable interest by local youth. Photo by V. Štědrá.

2018–2019

New geoscience methods for enhancing the quality of postgraduate studies in Ethiopia

■ Geresse, Gamo Zone, southern Ethiopia. Photo by L. Megerssa.



The main purpose of the development project was to enhance the professional knowledge of teachers and students of postgraduate geoscience studies, who in the near future will become the main pillar providing theoretical and practical solutions to the most important problems of contemporary Ethiopia. Individuals with completed postgraduate studies usually become key professionals who are engaged in teaching future university students as well as teachers and who will considerably help improve the quality of higher education in Ethiopia in the long term.

The main fields of theoretical and practical education were geosciences with emphasis on structural geology, petrology, thermodynamic modelling, geohazard analysis and applied geophysics.



■ Planning field work with a group of postgraduate students and GSE experts. Arba Minch, Gamo Zone, southern Ethiopia. Photo by T. Hroch.

■ > Interpretation of field data. Daye, Sidama region, southern Ethiopia. Photo by T. Hroch.

■ > Visiting local authorities. Tekeze, Tigray region, northern Ethiopia. Photo by L. Megerssa.





During the project, postgraduate lecture courses focused on expanding theoretical knowledge and on preparing international publications. In connection with these, two research projects were also carried out with the direct participation of students of doctoral studies, specifically involving the full scope of research ranging from the acquisition of field and analytical data to the preparation of professional publications. The results of the joint research were published as an IF-indexed scientific article.

■ << Kemba, Gamo Zone, southern Ethiopia. Photo by K. Verner.



■ Gohatsion, Amhara – Oromia region, central Ethiopia. Photo by K. Verner.

■ < Tomáš Hroch studying a fault in the Abay valley. Amhara region, central Ethiopia. Photo by K. Verner.

■ < Postgraduate course participants. Daye, Sidama region, southern Ethiopia. Photo by L. Megerssa.

1999–2005

■ Participants from the course visiting the North Bohemian lignite basin. The Merkur open cast mine is in the background. Photo by J. Pašava.

GEOCHIM/UNESCO: Postgraduate course in methods of geochemical exploration and their environmental applications



In the 1970s and 1980s the former Central Geological Institute, the predecessor of the present Czech Geological Survey, organized postgraduate GEOCHIM course under the auspices of UNESCO. These courses were specifically designed to train geologists in the methods used in geochemical exploration for mineral deposits and were attended by many geologists from developing countries. The courses were suspended in the late 1980s because of political and economic changes.

The GEOCHIM course was revived in 1999 at the request of the Czech Commission for UNESCO. Since then, the CGS has undertaken the organization of the course in cooperation with UNESCO. In addition to teaching standard methods of geochemical exploration, the content of the course was revised to



■ Training in the theoretical basis of hydrogeochemical exploration was supplemented by sampling of water in the field and by analysis in the laboratory. Photo by J. Pašava.



■ Measurements of total gamma radiation formed part of the practical training in the use of radiometric methods. Photo by J. Pašava.



■ Visits to the deep underground mine at Dolní Rožínka from which uranium is extracted were made during GEOCHIM/UNESCO courses. Photo by J. Pašava.

include environmental applications. As a result, many professional men and women from a range of countries attended the courses.

In 2001, GEOCHIM was incorporated in the Cooperative Development Programme of the Czech Republic for the period 2001–2004. As a result of the attention given to the organization and the quality of the scientific and practical content of the course, as well as promotion on the UNESCO and CGS websites and through papers published in international periodicals, the course has acquired an international reputation. The programme of lectures, seminars and practical training in the field took place at Dolní Rožínka, the site of the last underground uranium mine still in operation in the Czech Republic.

The training covered the following topics: (1) introduction to methods of exploration geochemistry, (2) fundamentals of environmental geochemistry, (3) basic methods used for geochemical analysis, (4) heavy mineral surveys, (5) stream sediment surveys, (6) soil geochemical surveys, (7) biochemical prospecting, (8) lithogeochemical prospecting, and (9) hydrogeochemical prospecting, (10) methods of geophysical exploration and their application to environmental assessment including radon risk, (11) computer processing of data and their interpretation. The emphasis in these topics was placed on the application of the various methods to environmental problems. Lectures in the morning were followed by practical training sessions in the field during the afternoon, including the use of the PC to store and analyze data.

Altogether seven GEOCHIM courses were successfully organized during the years 1999–2005 and 95 participants from more than 30 countries in Africa, Asia, South America and East Europe received training in the theoretical and practical aspects of applied geochemistry.

The conveners of the courses received many letters of appreciation from the participants on the course and also an award from UNESCO. Unfortunately, as a result of the reorganization of the Cooperative Development Programme of the Czech Republic in 2006, it became impossible to guarantee continued financial support for this internationally recognized course.



■ The training of participants took place in the grounds of the GEAM Department at Dolní Rožínka. Photo by J. Pašava.



As one of the largest deglaciated areas in Antarctica, the northern part of the Ulu Peninsula on James Ross Island provides an opportunity to study the relationship between glaciation and local volcanism in detail. This extremely interesting region has been the destination of many expeditions since the 1960s. Photo by B. Mlčoch.

RESEARCH AND DEVELOPMENT

CGS geologists are, as may be expected, also actively involved in improving global scientific knowledge and take part in interdisciplinary expeditions even to the most remote places in the world such as Antarctica, where they have made a number of unique discoveries of global significance on James Ross Island.

2006–2008

Back-arc volcanism in El Salvador and Nicaragua

■ Pyroclastic cone behind the main volcanic arc in inland El Salvador. Photo by V. Rapprich.



A detailed investigation of the geochemistry and isotopic composition of Tertiary to Recent volcanic rocks, which was carried out in an area lying behind the active volcanic front in El Salvador and Nicaragua, is closely linked to the findings of a geological mapping programme. To complement the geochemical data, comprehensive isotopic analyses of the elements Sr-Nd-Pb-Li-O were made and K-Ar dating was used. In El Salvador, particular attention was paid to interpreting the volcanism in the Ipala and Cinotepeque regions. The chemistry of lavas in these volcanic zones, which extend inland from the volcanic front, shows that the input of elements mobilized by fluid from the descending lithospheric plate decreases, but the influence of crustal fluids (the mixture of water and gases in the Earth's crust) remains surprisingly significant, only disappearing completely in areas most distant from the subduction zone. The study also revealed the effects of crustal contamination, even though quite weak.

Dating also gave interesting results. The ages obtained (1.6–2.4 Ma) are significantly older than anticipated from the results of earlier geological mapping. This is considered to be good news for the local population. The studies of volcanic rocks in eastern Nicaragua carried out by the Czech Geological Survey broke new ground by providing the very first geochemical data for a number of localities. Due to minimal infrastructure and difficult terrain, it was extremely difficult to reach the best localities and collect the necessary samples. The volcanic rocks turned out to be very varied and, altogether, four groups of rocks showing independent evolution were identified. One of these groups of volcanic rocks is obviously linked to the activity of the Miocene Coyol volcanic arc. The influence of subduction on the composition of the other groups was found to be minimal. Lead isotopes were used to identify rocks influenced by the Galápagos hotspot, which is of great importance in determining the extent of the CLIP unit that has further implications for the volcanic evolution of the Carribean region as a whole.

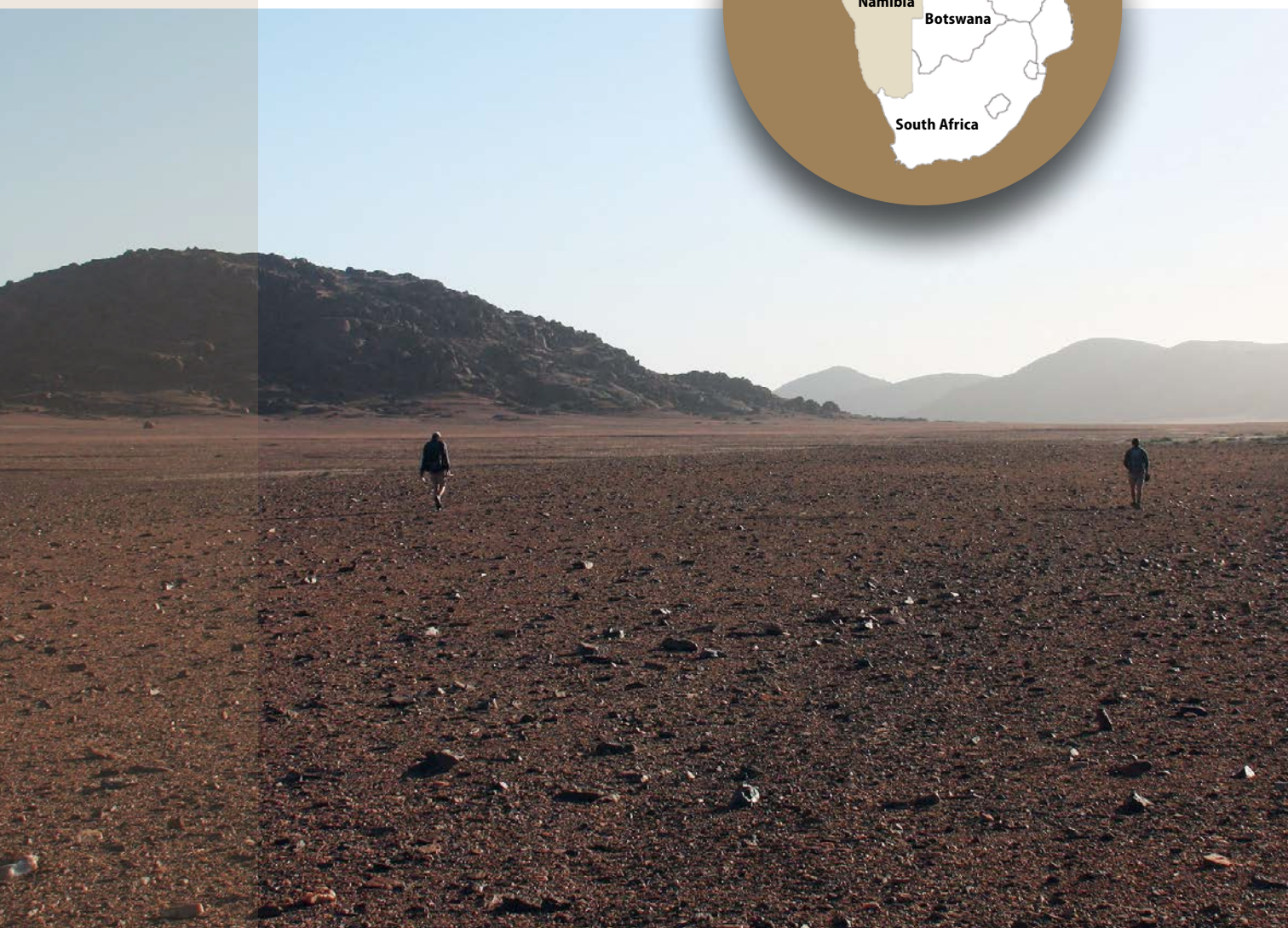
■ Documenting changes in the chemical composition of the pyroclastic rocks of the La Unión Formation and collecting samples for dating and chemical analyses. Photo by V. Rappich.



2007–2009

■ Typical scenery of the Namib hammada near the valley of the Sechomib River in northwestern Namibia. Photo by L. Tajčmanová.

Crustal evolution of the Kaoko orogenic belt in Namibia



The Kaoko orogenic belt in NW Namibia was chosen as an ideal terrain to investigate the relationship between structural evolution and successive episodes of magmatism during the evolution of an orogenic belt. The present project follows the long-term investigations carried out in this area by scientists from the Geophysical Institute of the Academy of Sciences of the Czech Republic. The Neoproterozoic Kaoko belt formed part of the Gondwana supercontinent and is one of best-exposed orogenic belts in the world. Magmatic rocks originated during four episodes of time covering the interval 840–550 Ma and are now

exposed in the high grade metamorphic domain forming the western sector of the belt. Samples of the granitoid rocks and associated mafic rocks from the four different age groups were collected for petrological examination and geochemical analysis. The results showed that the intrusives of the oldest group (~ 840–800 Ma) have relatively primitive compositions and are believed to have formed in a magmatic arc. These rocks originated through fractionation of mantle-derived magmas or via remelting of mantle-derived mafic rocks. In contrast, the geochemical characteristics of the younger granitoids (~ 730–550 Ma) indicate that the formation of these intrusives took place in several stages as a result of partial melting of sediments derived by erosion from rocks of the crust created by the older magmatic arc.

The second part of the project was concerned with the structural analysis of the western part of the Kaoko belt. Field studies of the sequence of deformation combined with dating of the metamorphic events and of some intrusive bodies shows that structural development was governed by oblique thrusting of the back-arc basin over the thinned edge of the Congo craton during the interval ~ 580–550 Ma. A change in the tectonic regime took place around 550 Ma due to extensive melting of the craton edge. Oblique overthrusting was replaced by transcurrent movements that resulted in the development of subvertical structures so that deformation became progressively focussed along steep shear zones during subsequent cooling of the whole orogenic belt.



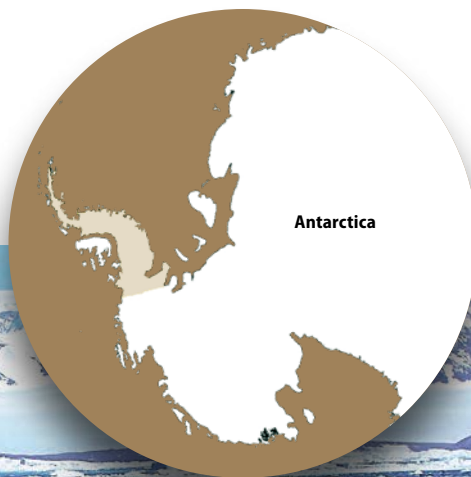
■ Valley of the River Hoanib in the southern part of the Kaoko belt in northwestern Namibia. Photo by S. Ulrich.



2007–2011

■ The Czech Antarctic Johann Gregor Mendel station on James Ross Island. The Antarctic Peninsula can be seen across the Prince Gustav Channel. Photo by M. Barták.

Investigations of the northern part of the Antarctic Peninsula and James Ross Island



A five-year project in four stages is being carried out by the Czech Geological Survey in the northern part of the Antarctic Peninsula and the northwestern part of James Ross Island.

Topographic, geomorphological and geological maps of the northern deglaciated part of James Ross Island were compiled at a scale of 1:25,000.

Subsequent detailed geoscientific studies were tied to the geological base map at 1:25,000 scale. Geochemical investigations carried out to determine the petrogenesis of the eruptive rocks and palaeontological studies of Cretaceous rocks formed an integral part of the project. Studies of the geological evolution of the wider area were supplemented by investigation of the structural-metamorphic processes and



■ The northern part of the Ulu Peninsula on James Ross Island is one of the largest deglaciated areas in Antarctica. It provides an opportunity to study the relationship between glaciation and local volcanism in detail. This extremely interesting region has been visited by numerous expeditions since the 1960s, but no geological map of the area exists. For this reason, the creation of a geological map of the northern deglaciated part of the island at 1:25,000 scale was the main objective of the project. The geologists seen here in the field are returning to Monolith Lake to continue in mapping after a snow storm. Photo by B. Mlčoch.

■ > Red Island in the Prince Gustav Channel is a typical example of a “tuya” (subglacial) volcano formed under an ice sheet. The upper horizontal lava flow solidified above the water level of the lake that formed due to volcanic activity. Photo by B. Mlčoch.

■ > Morning in a camp on the shore of St. Martha Cove on James Ross Island. Photo by B. Mlčoch.





rheological mechanisms governing the emplacement of the batholith in the magmatic arc on the Antarctic Peninsula. On James Ross Island, geomorphological mapping and descriptions of periglacial phenomena were added to the geological studies of the bedrocks. These investigations were carried out to obtain a better understanding of the abiotic processes that took place during individual cycles of climate changes in the Quaternary.

The main task of the climatological part of the project was to obtain better knowledge about the thinning of the ozone layer, changes in the intensity of UV radiation and changes in the behaviour of the upper troposphere and lower stratosphere. For this purpose, a Brewer spectrophotometer capable of recording and transmitting data automatically has been installed on Seymour Island.

The Czech biologists have focused on the birds and mammals of James Ross Island. They made detailed studies of the nesting biology, behaviour and population dynamics of the two most abundant bird species – the antarctic tern (*Sterna vittata*) and the antarctic skua (*Stercorarius maccormicki*).

The environmental part of the project is designed to identify and establish the concentrations and behaviour of organic pollutants that have been transported into Antarctica by wind and atmospheric precipitation. Long-term monitoring and assessment of the impact of the operation of the Czech Antarctic station on the quality of the surrounding environment has also been an integral part of the project.

■ << A view of the Czech Antarctic station on the shore of the Prince Gustav Channel seen from the helicopter. The summit of Bibby Point can be seen on the horizon. Photo by F. Holub.

■ The Czech geologists working in Antarctica succeeded in finding some remarkable fossils of the ammonite *Eupachydiscus* sp. The mother of pearl (nacre) of ammonites, pelecypods and gastropods is well preserved and has recently been found to be of great importance for studying the taxonomy and evolution of individual groups of molluscs. Shells of some molluscs are locally so abundant that they can be considered as an important rock-forming component. As many as a hundred shells can be found in one square metre at some exposures in the northern part of the James Ross Island. Among these can be found large well-preserved examples that are ideal for studying fossil mother of pearl. Photo by R. Vodrážka.



2009–2012

■ A view of the rapidly retreating Whisky Glacier from the top of Santa Marta Peak covered by a lichen of *Usnea* sp. Photo by D. Nývlt.

Glacial retreat on the northern part of James Ross Island



Changes in the areal extent and volume of small glaciers on the northern, mostly deglaciated, part of the James Ross Island were studied using methods of remote sensing and glaciological measurements in the field. Analysis and interpretation of satellite and aerial photographs showed that the Whisky Glacier has the fastest rate of retreat. During the last three decades, it has been shrinking at a rate of nearly 40 cm of water equivalent per year. The area of the glacier has diminished by more than 20% since 1977. The Davies Dome Glacier lies at a higher altitude. It has been shrinking at a slower average rate of 30 cm per year and its area has diminished by less than 15%. The data on the Davies Dome Glacier are similar to those obtained by Argentinean glaciologists from the Bahía del Diablo Glacier on nearby Vega Island.



■ The Triangular Glacier with its well developed terminal moraine. Photo by D. Nývlt.

■ Flysch sediments of the Trinity Peninsula Group (?Triassic–Lower Jurassic) tightly folded and deformed by brittle tectonics. Photo by V. Janoušek.



However, the field measurements of mass balance carried out on the Davies Dome Glacier since 2007 and on the Whisky Glacier since 2009 showed that both glaciers had a positive mass balance in 2007 and in particular in 2009, when the mass gain was more than 1 m. Nevertheless, these minor perturbations in annual mass gain and loss are superimposed on a general long-term trend of melting and retreat of terrestrial and shelf glaciers around the Antarctic Peninsula. The data acquired provide unambiguous evidence of this fast rate of glacier melting. Glaciers in the region of the Antarctic Peninsula are retreating due to an increase in temperature that is several times higher than in other parts of the Earth.

■ << Drilling a hole for an ablation stake on the surface of Davies Dome Glacier in 2009. Photo by K. Láská.



■ A detailed investigation of the nesting biology of antarctic terns (*Sterna vittata*) and antarctic skuas (*Stercorarius maccormicki*), shown in the photograph above), and southern gulls (*Larus dominicanus*) was carried out in the northern deglaciated part of James Ross Island. Thermometric dataloggers were installed to obtain records from 33 tern nests. This data will enable a better understanding of incubation behaviour and predation. Camera systems were installed at 16 tern nests to provide a continuous record of activity. Other nests have also been observed to gather information about the nesting biology of monitored species and the survival rates of chicks. Photo by V. Pavel.

since 2012

Study of the mechanisms of continental crust formation and evolution of accretionary orogenic systems in Mongolia

■ Base camp
at sunset after rain.
Photo by P. Hanžl.



This extensive research project focuses on studying the evolution of the accretionary system of the Central Asian Orogenic Belt and the mechanisms of new continental crust formation. The multidisciplinary research uses and combines the results of structural analysis, petrology, geochemistry, geochronology, geophysics, palaeomagnetism, and analogue as well as numerical modelling. The project is closely related to previous research, mapping and mineral deposit activities conducted by the staff of the Czech Geological Survey and the Institute of Petrology and Structural Geology, Faculty of Science, Charles University, and it is being carried out in cooperation with many foreign experts. The main focus is on the Mongolian and Chinese Altai and southwestern Mongolia, which form the core of the orogenic system. This region



■ Sunset begins over Terkhiin Tsagaan Lake (Arkhangai). Photo by C. Aguilar.

■ Research team of 2018. Photo by P. Hanžl.



represents a unique complete profile of a fossil accretionary system, which formed during a period spanning the Neoproterozoic and Mesozoic.

The age, character and mutual relations of individual lithotectonic units were investigated during the project. The research activities conducted show that the origin and evolution of the studied part of the Central Asian Orogenic Belt was driven primarily by the long-term existence of the gigantic subduction system of the Palaeo-Asian Ocean. This subduction system includes a complete sequence consisting of continental blocks, ophiolites, volcanic arcs and accretionary wedges. These results are followed up by a detailed study of tectonometamorphic and magmatic evolution, which allows for a reconstruction of the general accretionary evolution of the region. Gravimetric geophysical modelling provides information on the thickness and character of individual crustal units and their interfaces. It will contribute to understanding the deep architecture of the continental crust in this area.

■ << Playful colours in a valley of the Gobi in the Gobi-Altai Province. Photo by A. Guy.



■ Members of the CGS research team studying various deformation events observed in fine-grained metasediments containing intercalations of rhyolite. Northeast of the town of Bumbohur. Photo by C. Aguilar.

■ < Asymmetrical folding of Cambrian limestones due to the accumulation of crust in the brittle regime within the context of a passive margin, Taishir District. Age of structures 750–500 Ma. Photo by A. Guy.

The obtained information and results, which are continuously published in prestigious international journals, will be used to construct a synthetic model of the geodynamic evolution of the Mongolian part of the Central Asian Orogenic Belt, and they will also help gain a better general understanding of the main elements in the evolution of accretionary orogenic systems and mechanisms of continental crust formation.

PROJECTS

Page	Original titles of projects	Duration	Funding	Project manager
GEOHAZARDS				
6	Geological investigation of natural hazards in Northern and Central Nicaragua	2004–2009	MoE/MFA	RNDr. Petr Hradecký
6, 10, 14	Regional geological investigation to define and predict natural hazards in the central part of Central America (Nicaragua, Costa Rica, Salvador)	2007–2009	MoE/MFA	RNDr. Petr Hradecký
14	Regional geological investigation to define and predict natural hazards in the central part of Salvador (San El El Salvador, Cuscatlán and La Libertad)	2003–2005 2007–2009	MoE/MFA	RNDr. Petr Hradecký
18	Assessment of natural hazards in the middle and upper reaches of the catchments of the Chira and Piura rivers in northwestern Peru, definition of criteria for the prediction of natural hazards and the mitigation of their impacts	2003–2006	MoE/MFA	Mgr. Daniel Nývlt, Ph.D.
18	Investigation and exploration of geomorphological features in the Piura River basin in order to reduce environmental hazards affecting socio-economic development of the region, Peru	2007–2010	MoE/MFA	Mgr. Michal Rajchl, Ph.D.
22	Evaluation of landslide susceptibility in the mountainous parts of Georgia on the example of endangered settlements, international roads and energy conduits in the Dusheti Municipality	2014–2017	Czech Development Agency	Mgr. Aleš Havlín, Ph.D.
26	Capacity building in environmental geology – Mapping of geohazards including hydrogeological conditions in the Dila and Hosaina areas	2012–2014	Czech Development Agency	Mgr. Vladislav Rapprich, Ph.D.
30	Study of natural phenomena deleterious to agricultural production in selected zones of the SNNPR (Southern Nations, Nationalities and People's Region)	2015–2018	Czech Development Agency	doc. RNDr. Kryštof Verner, Ph.D.
ENVIRONMENTAL GEOLOGY				
36	Impacts of mining and mineral processing on the environment in the mining districts of Namibia	2004–2006	MoE/MFA	doc. RNDr. Bohdan Kříbek, Dr.Sc.
40	Exploration for water resources in areas affected by drought (Ethiopia)	2006–2008	MoE/MFA	RNDr. Jiří Zvelebil
44	Assessment of the impacts on the environment in the Copperbelt Province of Zambia caused by mining and mineral processing of copper-cobalt ores	2004–2006	MoE/MFA	doc. RNDr. Bohdan Kříbek, Dr.Sc.
44	Addressing the impact of mining and mineral processing on the environment and human health in selected regions of the Central and Copperbelt provinces in Zambia	2008–2010	MoE/MFA	doc. RNDr. Bohdan Kříbek, Dr.Sc.

Page	Original titles of projects	Duration	Funding	Project manager
48	Impact of ore mining and processing on the environment in the Copperbelt Province, Zambia: A model of heavy metal and sulphur cycles in soils, sediments, water and vegetation	2008–2010	GACR	doc. RNDr. Bohdan Kříbek, Dr.Sc.
52	Monitoring dust fallout from the smelter at Nkana and environmental education of students in high schools at Nkana, Wusakile and Mukuba in the city of Kitwe in Zambia	2008	MoE/MFA	doc. RNDr. Bohdan Kříbek, Dr.Sc.
MINERALS				
58	Assessment of gold resources remaining after artisanal mining in Burkina Faso and the possibility of their future exploitation	2003–2005	MoE/MFA	RNDr. Jan Pašava, CSc.
62	Tectonic evolution and the prediction of the mineral potential in West Africa	2010–2013	contract	doc. RNDr. Bohdan Kříbek, Dr.Sc.
66	Geological mapping at 1:50,000 scale in selected regions of Mongolia	2003–2007	MoE/MFA	RNDr. Pavel Hanžl, Dr.
70	Assessment of exploration licenses granted to the Moravia Steel Company, Mongolia	2008–2012	contract	RNDr. Petr Mixa
74	Assessment of the mineral resources of the gold and platinum deposit at Ongon Ulaan Uul in the southern Gobi, Mongolia	2009	contract	RNDr. Antonín Seifert, CSc.
76	Geological mapping at 1:50,000 scale and evaluating the economic potential of a selected area in Western Mongolia	2013–2016	Czech Development Agency	RNDr. Vladimír Žáček
78	Assistance in redevelopment of geological institutions and organizations in Afghanistan with emphasis on the exploitation of mineral resources	2005–2007	MoE/MFA	Ing. Ilya Kněsl
82	Assessment of prospective deposits of iron and manganese ores in Iran	2010–2012	contract	RNDr. Petr Mixa
86	Investigation of platinum group elements (PGE) and their distribution in large gold and copper deposits of Uzbekistan	2007–2009	MEYS	RNDr. Jan Pašava, CSc.
90	Investigation of the distribution of platinum group elements (PGE) in the Polar Urals	2007–2009	MEYS	RNDr. Jan Pašava, CSc.
EDUCATION				
96	Capacity building of Geological Survey of Iran staff in geological mapping at 1:25,000 scale of selected map sheets in the Eastern Azerbaijan Province of Iran	2006–2010	contract	RNDr. Jiří Babůrek, Ph.D.

Page	Original titles of projects	Duration	Funding	Project manager
100	Improving the quality of university education in the applied Earth sciences focused mainly on geohazards and hydrogeology	2013–2015	Czech Development Agency	Mgr. Vladislav Rapprich, Ph.D.
104	PanAfGeo: Geoscientific knowledge and skills in African geological surveys	2017–2019	European Union	Mgr. Veronika Štědrá, Ph.D.
108	Implementation of a methodical approach in geological sciences to enhance the quality of doctoral studies at Addis Ababa University, Ethiopia	2018–2019	Czech Development Agency	doc. RNDr. Kryštof Verner, Ph.D.
112	GEOCHIM/UNESCO – New geoscience methods for enhancing the quality of postgraduate studies in Ethiopia	1999–2005	MoE/MFA	RNDr. Jan Pašava, CSc.
RESEARCH AND DEVELOPMENT				
118	The origin of magma in a continental back-arc environment: geochemical and isotopic variability in the central part of the Central American volcanic arc	2006–2008	GACR	Mgr. Vojtěch Erban, Ph.D.
120	Relationship between tectonics and episodes of magmatic activity during the evolution of orogenic belts – the example of the Kaoko orogenic belt in NW Namibia	2007–2009	GACR	Mgr. Jiří Konopásek, Ph.D.
122	Contribution of the Czech Republic to stabilization of the ozone layer and solar UV radiation in Antarctica, palaeoclimatic and palaeogeographic reconstruction of a selected part of Antarctica and related geological study and mapping	2007–2011	GACR	RNDr. Petr Mixa
126	Recent deglaciation of the northern part of James Ross Island, Antarctica	2009–2012	GACR	Mgr. Daniel Nývlt, Ph.D.
130	Mechanisms of continental crust formation and evolution of accretionary orogenic systems (Mongolia, Central Asian Orogenic Belt)	since 2012	GACR	Bc. Daniela Joštová

Czech Geological Survey Abroad

Published by the Czech Geological Survey,

Klárov 3, Prague 1

Editor Petr Maděra

Executive editor Šárka Sedláčková

Cover Eva Šedinová

Layout and graphic design Oleg Man

Printed by the Publishing Department
of the Czech Geological Survey

03/9 446-415-19

© Czech Geological Survey, 2021

ISBN 978-80-7075-967-7



The Czech Geological Survey

The Czech Geological Survey was established shortly after the foundation of Czechoslovakia in 1918. The growth of industry in Europe and the turbulent years of the First World War had emphasised the crucial role that raw materials would play in underpinning the social and economic structure of the state. Without coal, oil, natural gas, minerals, water, and industrial raw materials for ceramics, glass and construction purposes, as well as the uranium later used for the generation of nuclear power, material civilization as we know it would not be possible. The fact is that all these resources are obtained from the rocks beneath our feet, but their discovery, measurement and extraction depend directly on a full understanding of the geological context in which they are formed and the conditions that favour their preservation in the Earth's crust. This is the domain of the geological sciences.

Under the terms of its articles of foundation, the CGS serves as the geological service of the Czech state and thus takes responsibility for gathering, storing and interpreting information about the geology of the territory of the Czech Republic. It is a state-subsidised organization that has the status of a Research Institute of the Czech Ministry of Environment. It is the only organization with the statutory duty to carry out systematic geological mapping and investigation of the whole country.

The national and international reputation the Czech Geological Survey is based on the integration of services for society with excellence in research in the fields of geological sciences, natural resources, geological hazards and environmental protection. Because of the range of experience acquired over almost a century of applied scientific research at home and abroad, the CGS can also offer assistance to developing countries in exploring for natural resources, monitoring environmental problems and developing policies for sustainable development. Through its programme of publications and public outreach activities, the CGS plays an important role in the popularization of geology and education of the wider community.

Major fields of activity

- geological investigation and mapping
- evaluation and protection of the rock environment
- assessment of mineral raw materials and the impact of mining on the environment
- identification of geological hazards, their prevention and mitigation
- storage, management and provision of geoscientific information

Statutory functions

- Geological mapping and regional research within the territory of the Czech Republic
- Basic and applied research on geohazards, mineral resources, groundwater sources, rock environments and environmental protection
- Serves as the state geological survey in accordance with Act No. 62/1988 Coll. (on geological work)
- Gathering, compilation and interpretation of data on the geological structure, mineral resources and geohazards of the CR
- Provision of geoscientific information and expert advice to support decision-making on issues of state and public interest
- International cooperation and foreign development aid
- Education in geosciences and environmental protection

Vision

The Czech Geological Survey seeks to fulfil its role by providing geoscientific data and expert advice of the highest quality to the state authorities so that informed decisions can be made about policies affecting natural resources, natural hazards and sustainable development. It will build and strengthen its expertise through innovative research and international cooperation in the EU and overseas in order to maintain its reputation as a leader in the field of Earth sciences.



www.geology.cz

