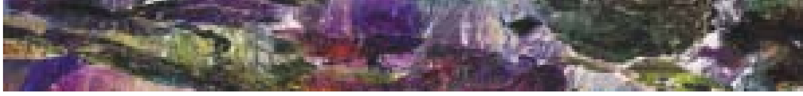


Czech Geological Survey

Development Assistance Projects

Science
Education
Partnership

Czech Geological Survey

Since 1919

Mission

- collecting, assessment and dissemination of data on the geological composition, mineral resources and natural risks of the Czech Republic
- providing geoscience information and support to the authorities for the political, economical and environmental decision-making
- international cooperation and development aid
- education in geosciences and environmental protection

Main areas

- geological research and mapping
- environment and pollution
- mineral resources and mining impact
- prevention of natural risks
- management and delivery of geodata

Staff

314 employees (~263 load equivalent), including more than 175 research workers (December 31, 2003)

Budget

165 million CZ (~5.3 million EUR, in 2003)

Legal status

A state research institute supervised by the Ministry of Environment of the Czech Republic

Ministry of Environment
of the Czech Republic

www.geology.cz

Contents

Foreword

CGS since 1919: Science – Education – Partnership

Headquarters of the Czech Geological Survey, Prague-Klárov.

In 1996 the Czech Republic, as a new member state of the Organisation for Economic Co-operation and Development, launched the national Official Development Assistance Program. Since then, the Czech Geological Survey has proposed and carried out a number of projects within this framework. An overall mission of the Program of the Czech Republic is to contribute to alleviating poverty in less developed countries through the promotion of sustainable development.

Within the Czech Official Development Assistance Program, the CGS has accomplished projects in Nicaragua (since 1997), Zambia, Namibia, Burkina Faso, Mongolia, El Salvador, and Peru. We have also developed the GEOCHIM postgraduate training course (since 1999).

The main goals of the projects are as follows:

- geological mapping and research (Nicaragua, Mongolia, Zambia)
- evaluation and risk assessment of geodynamic processes (seismic and volcanic activity, landslides, erosion and floods) in Central and South America
- research on mineral resources, including assessing the economic potential of selected areas in Africa (Zambia, Namibia, Burkina Faso)
- impact of anthropogenic activities on the environment (Burkina Faso, Zambia)

To achieve results of the highest quality in these projects, CGS utilizes its staff of leading experts with broad international experience. For most of the analytical work involved, CGS can rely on its own accredited laboratories.

The results of the projects are highly appreciated by the authorities in the partner countries, as they provide vital information for the further growth of these countries, whether in classifying hazardous areas or indicating mineral resources. Our projects often include the specialized training of young earth science professionals in the partner countries.

Since the mid 1990s these projects have allowed CGS to successfully revive professional international partnerships that had been established 30–40 years ago (e.g. Mongolia and Nicaragua).

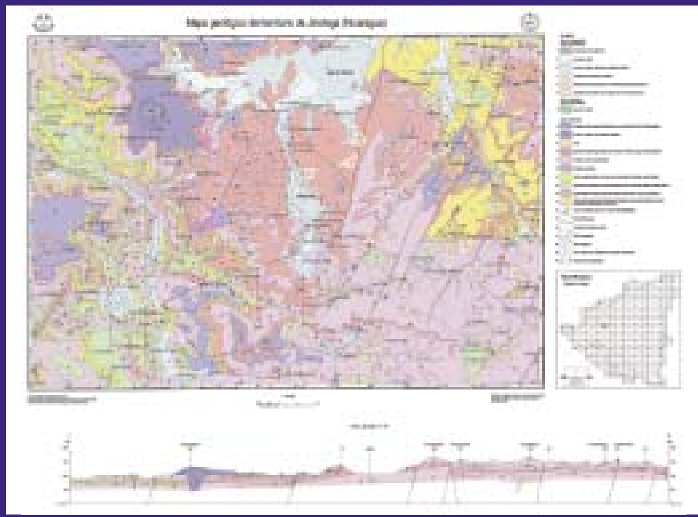
Since 1999, the Czech Geological Survey has enforced the quality management system (QMS), pursuant to the international standard ISO 9001. The QMS has been adopted and implemented within the main activities and products of the survey, such as geological mapping programs and expert opinions, as an indicator of quality at the national and international levels.

Zdeněk Venera
Director of the Czech Geological Survey

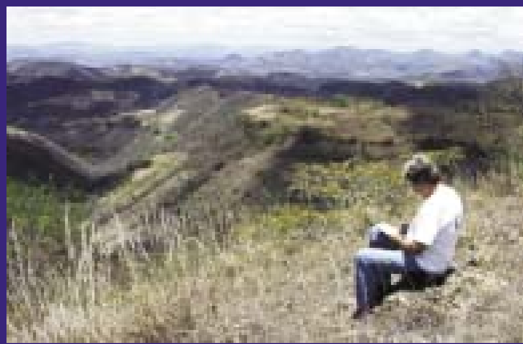
Geological Mapping & Research

Geological & Thematic Mapping
Regional & Special Geological Research
3D Modeling & Geoinformation

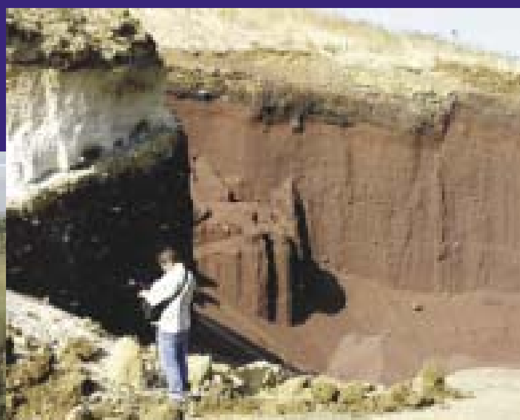
Geological mapping and the evaluation of geological settings, complemented with regional and specific geological research, represent fundamental methods involved in all CGS development assistance projects. Geological maps provide an invaluable prospecting for mineral deposits, evaluating contaminated areas, or assessing natural hazards such as landslides and flooding. The geological information contained in these maps constitutes a basis for territorial development and resource management. Geological mapping and field observations are now always undertaken with the assistance of GPS location devices, notebooks for collecting and managing field databases, or enhanced satellite imagery. These modern geological methods require multidisciplinary teams that are skilled in their use, and that are trained in the application and processing of various kinds of geodata sets.



Digital geological map 1:50,000, Jinotega, Nicaragua.



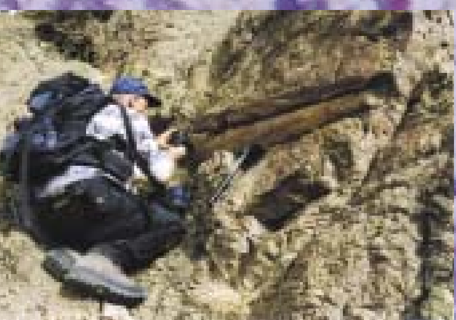
Geological mapping in the mountainous Matagalpa area, central Nicaragua.



Documentation in the cinder cone, Managua, Nicaragua.

Geological mapping & documenting of a reference point, Mongolian Altay.

Detailed geological documentation of quartz bodies at the Choaberib area, Namibia.



Documentation of the petrified wood in the Permian volcano sedimentary sequence, Mongolian Altay.

Dunes of the Namib desert, Namibia.

Jointing and spherical weathering of granites, Weissenfels, Namibia.

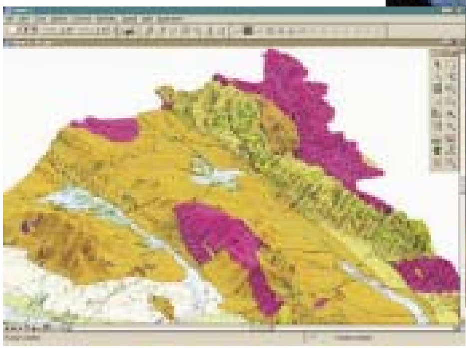
Projects

Evaluation of the geological setting in the vicinity of Muyombe, Zambia (1999–2000)
Geological studies of natural hazards in Nicaragua (1997–2006) and El Salvador (2003–2005)
Geological mapping of selected areas of Mongolia (2003–2006)

Regional mapping project – Muyombe and Luwumbu River areas, NE Zambia

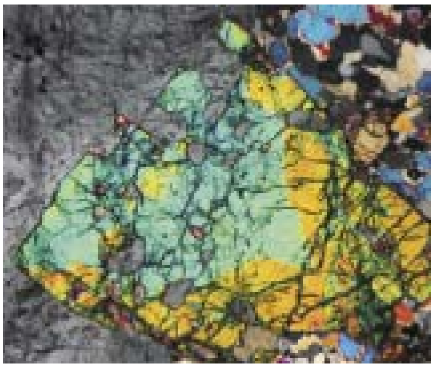
The regional mapping at a 1:100,000 scale, with assessment of the geo-potential of Muyombe-Luwumbu terrain, was initiated in 1999 as a joint project involving the Czech Geological Survey and the Geological Survey of Zambia, with the collaboration of the British Geological Survey, as part of the ERIPTA project supported by the World Bank. The major objectives were to carry out regional geological mapping and to assess the mineral resources of an area of about 4 500 km^2.

The acquisition of basic geological field information involved the gathering of geological, structural, metamorphic, geochemical, and geochronological data in this remote and unmapped area. The project covered a multidisciplinary program toward establishing the geological and structural evolution of NE Zambia, with a special emphasis given to the mineralisation and the field evaluation of industrial mineral resources. On-going geochronological and geochemical studies helped to refine the stratigraphic framework of the area and provided the basis for regional correlations.



The 3D model of the Luwumbu River area in NE Zambia, view from SW.

View from top of the Mitanga Hill towards Nyika Escarpment, with Luwumbu Valley in the front.



Corroded crystal of chrysoberyl 0.5 cm long, associated with beryl (grey) and quartz, Kalanga Hill, crossed polars.

Folded migmatite in the Lusabo River, Sitwe area, NE Zambia.

Foliated orthopyroxene-biotite enderbite with a dyke of metadolerite. Structure of orthopyroxene enderbite: hypersthene (pale brown), plagioclase (nearly white), ilmenite & magnetite (black), minor biotite. Single polar. Sitwe area, NE Zambia.

The Paleoproterozoic basement in the Muyombe and Luwumbu River areas of northeastern Zambia comprises a WNW-ESE (to E-W) trending cordierite-garnet-sillimanite granulite unit with numerous enderbite bodies and an amphibolite-facies migmatite unit. Zircons from a biotite metatonalite that intruded the granulites were dated at 1960.7 ± 0.4 Ma. Mesoproterozoic intrusions into this basement are represented by a nepheline syenite at Mivula Hill (zircon age: 1360.1 ± 0.8 Ma) and the porphyritic Ntendele biotite metagranite (zircon age: 1329.1 ± 0.6 Ma). The Mesoproterozoic greenschist-facies Mafinga Group occurs in two major belts imbricated in the basement. Mylonitization affecting the basement complex near the Mafinga Group slices resulted in strongly sheared domains with a corresponding Irumide-age structural and metamorphic overprints (JOURNAL OF AFRICAN EARTH SCIENCES, 2004, 38, 1–21).

New prospective Cu-Cr-Ni-Zn stream sediment geochemistry anomalies were delineated. Interesting dispersion aureoles of pyrite and arsenopyrite, abundant gem quality tourmaline, and Cr-pyrope with associated pyroxene were found in the heavy mineral concentrates.

Pegmatite swarms that may be a source of economic minerals (chrysoberyl, beryl, topaz) are mainly confined to certain areas of Makutu Hill and Kalanga Hill ridges. Good quality ceramic raw materials can be obtained from some pegmatites of the Mivula Hill Prospect. The mapping also revealed new localities with possible supplies of dimension stones (nepheline syenite, gabbroic and dark charnockitic rocks) suitable for block quarrying and decorative uses.

Geological mapping and reconnaisance study of the eastern Mongolian Altay

The objective of the project is the compilation of a 1:50,000-scale geological map accompanied by a reconnaissance study of the mineral resources in the Mongolian Altay east of Chandman Somon. The investigated area measures approximately 3,500 km^2. The digitized maps are customer-oriented and will be used by government administration and for follow-up prospecting. The field work, executed on ten 1:50,000 map sheets, will have a step-wise character, and is done in co-operation with junior Mongolian geologists who are acquainted with the most modern geological mapping and computer-processing methods.

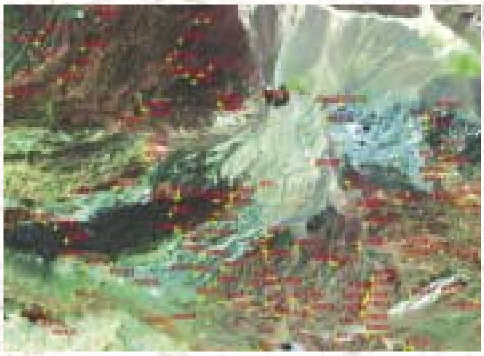
A look to the south from the ultrabasite body of the Erdene Uul, Mongolian Altay.

Crossed plagioclase laths in subvolcanic basalt of unknown age.

The 2004 camp was situated in the Khangiyn Gol valley at an altitude of almost 2500 m, approximately 17 km SE of the Chandman Somon district town. The expedition staff was comprised of ten Czech geologists, one Mongolian geologist, five drivers, three labourers, and five student-trainees from the Mongolian Technical University. The work groups were comprised of Czech and Mongolian members. Three groups focused on field mapping, while another three collected and processed geochemical samples and assessed aspects of the economic potential of the local geology.

The main objectives of the 2004 field season were to carry out preliminary traverses, to collect pilot samples, to investigate several geological anomalies of economic interest and paleontological localities, and to begin systematic geological mapping and geochemical prospecting.

The members of the expedition also engaged in social and representative functions. The Chandman Somon district town celebrated the 80th anniversary of its establishment during tour expedition. Our staff-members were officially invited to participate in this celebration.



Map of reference points over a Landsat image, Mongolian Altay 1:50,000-scale mapping.

Well preserved fossil of a Lower Cretaceous mayflay larva.

The expedition members were invited to participate in the festivities of Chandman Somon's 80th anniversary, July 2004.

Canyon in the Lower Cretaceous sandstones and conglomerates of deltaic origin, Mongolian Altay.

The field camp of the CGS expedition in the Mongolian Altay, Mongolia, 2004.

Geological mapping for natural risk assessment in Nicaragua and El Salvador

Geological mapping and the compilation of maps in 1:50,000 scale serve as a basis for further activities within the projects carried out by the Czech Geological Survey in Nicaragua and El Salvador. Modern mapping had not been conducted in either country, since international projects in Central America are usually short-term studies. The CGS projects are regional, and therefore cover large areas by uniform methods.

In the framework of the geological mapping, the natural and man-made outcops have been documented and sampled. The analyses done by the CGS laboratories determined the mineralogical and chemical composition of rocks and raw materials. Detailed geological mapping, including photogeological interpretation and satellite image analysis, provides a basis for the compilation of the hazard map and documents topographical development at the same scale. Areas in which landslides occurr are marked in the maps and mentioned in the reports, as are fault lines and their possible relationship to earthquake hazards. In the framework of the thematic mapping, an engineering geological map has been compiled at the scale 1:50,000. This map provides a principal basis for the planning of land-use and development. During the geological mapping activity, the hydrogeological conditions have been also assessed and some resources of building raw materials were found, for instance new deposits of perlite.

The results of geological mapping and thematic research have being given to the local authorities in the form of printed maps, GIS solutions and 3D models of assessed areas. These data are used as very important decision-making tools. The quality of the visual presentation of geological conditions, and the consequent risk assessments, help to convince politicians and decision-makers to enforce the latter in territorial planning.

The training of local geologists is an integral part of the fulfillment of our projects. Neither in INETER nor in SNET are there sufficient numbers of skilled specialists who would be able to carry out the regional geological studies. Therefore, some of them are trained in the field, and they are also helpful during the compilation of final reports.

Pyroclastic flows and surge, flanks of the Apoyeque volcano, Nicaragua.

Young slag deposits, slopes of the Telica volcano, Nicaragua.

Road cut in Ilopango pyroclastic flows, El Salvador.

Faulting in Quarternary Ilopango ignimbrites, El Salvador.
The Ilopango caldera is a very dangerous volcanic centre close to the country’s capital. Voluminous silicic ignimbrites and ash-falls were produced by explosive events that had occured several times during the Pleistocene and Holocene. The youngest of these had a destructive effect on a Mayan settlement in the area.
Indurated and welded ignimbrite deposits are higly dissected by series of young faults, as seen in the road cut near San Salvador. Both volcanic and tectonic hazards make all the metropolitan areas very vulnerable.

Geological & Natural Hazards

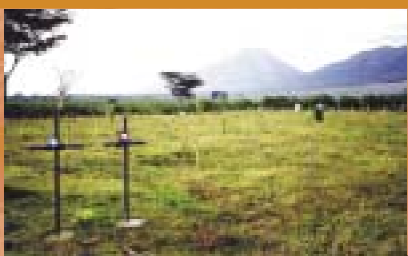
Geological Hazards & Risk Assessment
Support of Development Planning
Engineering Geology & Hydrogeology

Geohazards such as volcanic eruptions that trigger pyroclastic and lava flows, associated surges, lahars and edifice collapces, seismic instability, landslides, floods endanger hundreds of millions of people worldwide. Natural hazards represent risks mainly for developing countries. Reducing the risk potential is a priority of development assistance projects carried out by the projects of the Czech Geological Survey in Nicaragua, El Salvador, and Peru. Based on modern geological mapping, engineering and hydrogeological surveys, photogeological methods and satellite image analysis, the CGS compiles hazard maps and risk assessment studies. The results of these activites are communicated to the local authorities in the form of digitally processed maps, GIS and 3D models to support the decisions behind territorial planning and development.
The CGS also helps to reduce the lack of skilled geologists in these countries by providing various forms of training to the local staff.

San Cristóbal volcano, Nicaragua 1999.

Collapsing crater rims of the Masaya volcano, Nicaragua.

Nicaraguan and Czech geologists at the Masaya volcano shortly after its sudden blast in 2001, Nicaragua.



National cemetery for the victims of huricane Mitch, with the Casita volcano in the background, Nicaragua.

Basaltic aa lava produced by the San Salvador volcano in 1917, El Salvador.

Presentation of results to the director and personnel of SNET, San Salvador 2004.

3D model of the part of the Pacific volcanic belt area around the El Hoyo volcanic complex and the Telica volcano, Nicaragua.

The President of Nicaragua, Eng Enrique Bolaños Géyer, greeted the CGS group in Somoto during a public meeting during the state program for developing of the Madriz Province. 31 March 2004, Somoto.

Projects

Geological study of natural hazards in the western and central part of the Pacific zone in Nicaragua (1997–2006)

Geological study of natural hazards in Salvador (2003–2005)

Assessment of the natural hazards in the central and upper part of catchment of the rivers Chira and Piura, NW Peru (2003–2006)

Geological study of natural risks in Nicaragua

The project in Nicaragua began in 1997. The first study was localized in the capital, Managua, where “all the eggs are in one basket“, as the local people say. The capital of Nicaragua was totally destroyed during the 1972 earthquake. A detailed study of volcanic stratigraphy and the location of the main faults is important for all construction activities in the city. The priority of Managua was later confirmed by a project for studying faults, organized and financed by international institutions and the World Bank, and in which several Czech geologists participated.

Studies in 1998 involved volcanological and geological field work in the seismically and volcanically active area of Granada–Apoyo, where newly recorded faults were activated one year later during the catastrophic earthquake. Hurricane Mitch hit Nicaragua at the end of October, 1998. The western part of the country suffered considerable damages. The most damaged areas of the Casita Volcano and its surroundings were the subject of the Czech group’s 1999 study. The results of this detailed evaluation of the vulnerable neighbouring areas were immediatelly submitted to the local authorities for deciding on the further reconstruction of damaged areas.

Studies of natural risks in the Pacific region were completed in 2001. This entire region is endangered by the activity of recent volcanoes such as Cerro Negro, Telica, El Hoyo, Momotombo, Apoyeque and Cosigüina. The seismic instability of the area increases the danger, especially in areas along some young faults. Cities such as Chinandega and León are continuously exposed to volcanic danger, consisting of ash-fall, lava flows, and gas emanations. The Cerro Negro eruption in 2000 generated associated faults near the volcano, while seismic unrest in 2001 occurred in the vicinity of the Momotombo volcanic slopes where at geothermal power plant is situated. A detailed study of the eruptive history of the famous Cosigüina volcano enabled the understanding of the processes that could induce such catastrophic events as occurred in 1835.

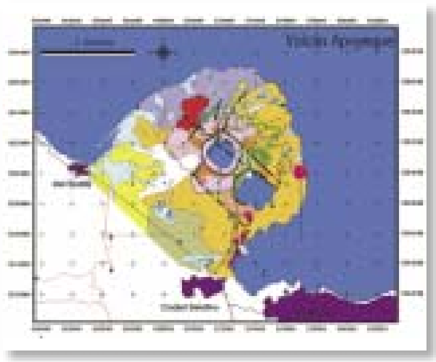
During subsequent years the activity of the Czech geologists has been concentrated in the hilly region of central and northern Nicaragua, namely the provinces of Matagalpa, Jinotega, and Somoto. Similar to many parts of the country, these mountainous areas have been affected by natural disasters related to geological structure, rock composition, weathering, and deforestation. The demarcation of vulnerable areas together with suggestions on how for designing houses, linear constructions and agricultural facilities for avoiding future damage are the major objectives of the Czech Geological Survey’s team.

A landslide damaged this church in the village San Simón de Palsila near Matagalpa, 2002.

Destructive debris flow on the slopes of the Casita volcano caused by hurricane Mitch, 1998.

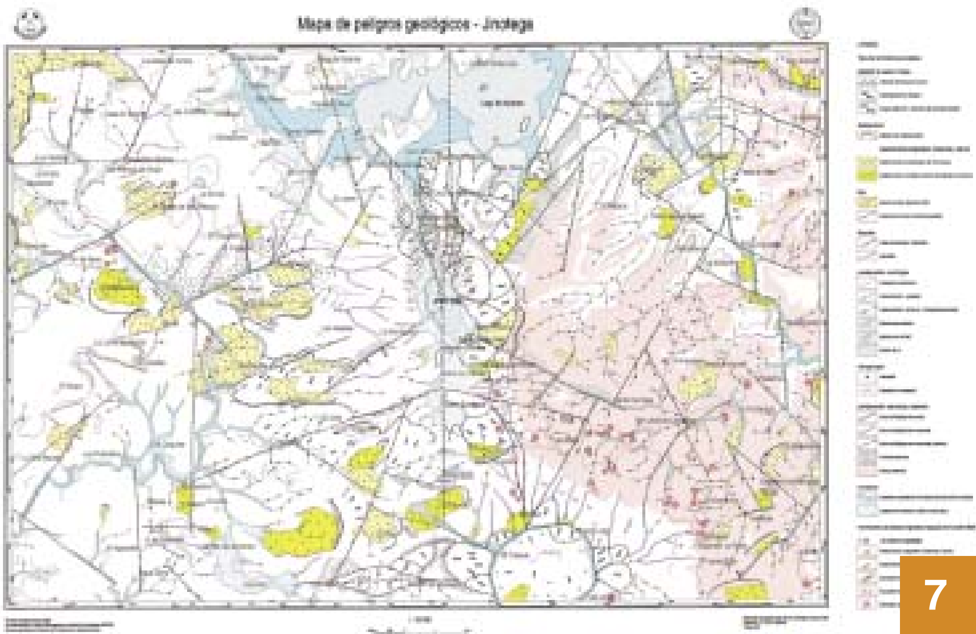
Lake Managua after the 1998 Mitch floods.

New faults opened during the 2001 Cerro Negro explosion.



Geological map of the Managua area and neighbouring Apoyeque volcano.

A map of geological risk, 1:50,000, Jinotega, Nicaragua.



Geological studies of natural hazards, El Salvador

The geological conditions and the degree of vulnerability in geologically complex and economically important areas have been studied, including five Salvadorian islands in the sensitive border area of the Gulf of Fonseca, and other regions north of the country's capital.

Geology, geomorphology, and the impact of human activity are the main factors that affect the type and extent of risks in the selected area. This multidisciplinary project has included geological mapping, the study of geodynamic processes, volcanological analysis, studies of the youngest deposits, and geological engineering.

The field work consisted of several operations involving geological mapping and the compilation of a map in 1:50,000 scale. This map has served as a basis for further activities. Modern mapping had not been conducted in either country, since international projects in Central America are usually short-term studies. Our projects are regional, and therefore cover large areas by uniform methods. Geological maps provide useful information for interpreting geomorphology. They are also crucial in the creation of maps and reports on geological hazards, including risk evaluation, locating vulnerable areas, specifying the kinds of risks and their potential prediction. The results are provided to local authorities in GIS and printed forms.

El Salvador is frequently affected by natural disasters that are closely related to geological conditions (hurricanes, landslides, rock falls, floods, and volcanic and seismic activity). For such a small and densely populated country, the risk assessment data are very important. Loss of life, damage to infrastucture and private property, the destruction of agricultural areas, and the disruption of the lives of thousands of people are the common results of such events. This is why the study and prediction of natural hazards have priority.

The activities of the Czech Geological Survey in El Salvador began in 2003, in cooperation with the newly established governmental institution SNET (Servicio Nacional de Estudios Territoriales). During two periods of research, new data were acquired from the easternmost region of the country, from the Salvadorian islands in the Gulf of Fonseca, and from central El Salvador. Geological and structural patterns are highly complicated in these vulnerable areas, where various stages of weathering and the tectonic deformation of volcanic rocks signaled diverse types of risks. In 2004 the field work was supplemented by remote sensing evaluation.

The new data serve the purposes of land planning and evaluating the most endangered areas. They are also of use to the Civil Defense for making evacuation plans, as well as for general education.

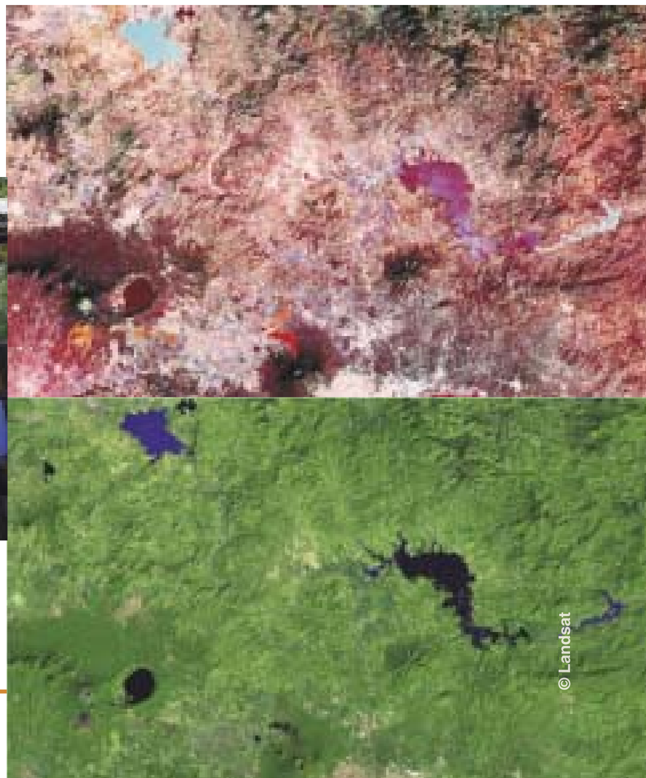
Geologists on Meanguera island, Gulf of Fonseca.

Volcanic island Conchaguita, Gulf of Fonseca.

Reseach in the field: Salvadorian and Czech geologists on the Juan Pancha volcano, eastern El Salvador.

The catastrophic landslide triggered by the 2001 earthquake, Santa Tecla.

The study of thermal gradient using Landsat images (7-6:5:7, ev. 7-7:5:3).



Field measurements of the physical and chemical parameters of waters.

Volcanic landscape of the central El Salvador.

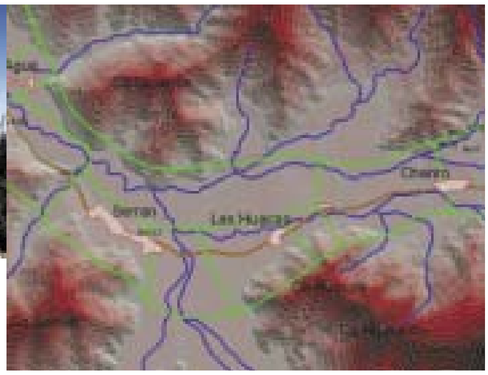
Natural hazards in the central and upper catchment areas of the Chira and Piura rivers, NW Peru

This project involves geological, geomorphological, and hydrological studies focused on documentating, defining, and predicting of natural hazards. Floods, landslides, and erosional and depositional features are frequent phenomena that damages communications, settlements, and agricultural land in the catchment areas of the Chira and Piura Rivers.

New studies evaluating the degree of natural hazards provide a very important basis for the economic development of the region. The final product of the project will be a computer information system (GIS) covering individual layers: natural hazards, geology, geomorphology, and hydrology, and will contain the text of reports and hydrological models of inundation areas and bases for water management in the Chira and Piura River catchments. The potential for predicting natural disasters and minimizing their damages is also being investigated.

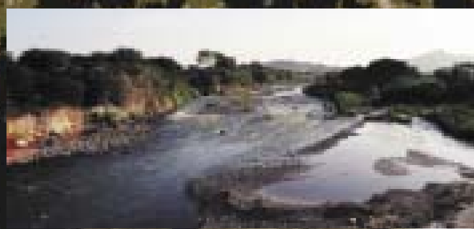
Strongly deformed slopes of the upper Piura River catchment area above the Canchaque, with a typical dormant landslide (center left).

Rotational landslide initiated by undercutting of the slope during the road construction between the towns of Canchaque and Hauncabamba.



3D-model of the middle course of the Piura River with the wide floodplain at the confluence with a tributary called Rio Seco.

Meanders and cut-off meanders of the Chira River and its tributaries as viewed from space by the Ikonos satellite.



Channel fill of the Rio Chipillico, left tributary of the Chira River at a low flow rate.

Longitudinal bars in an anabranching river channel during low flow rate on the lower course of the Piura River.

Mineral Resources & Prospecting

Identification and Assessment of Resources
Sustainable Use of Mineral Resources
Mitigation of Mining Impact

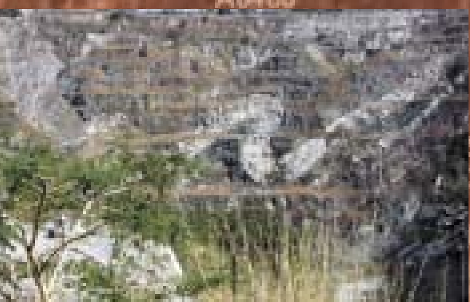
Various silicic materials fill fissures in ignimbrite deposits in Nicaragua. Some of these could be used as semiprecious stones.

Ensuring the supplies of necessary minerals for local industry and/or export is an important issue for the governments of developing countries. Therefore, the sustainable management of mineral resources is becoming increasingly important for such countries.

The identification and evaluation of new mineral resources is an integral part of the regional aid-funded development projects carried out by the Czech Geological Survey. These projects involve regional geochemical prospecting, field and laboratory assessment of mineral occurrences, technological studies of raw materials, and evaluating the environmental impact of existing or potential mining under a country's specific conditions. Our CGS geologists involved in the development assistance projects provide knowledge and training to the employees of local geological surveys concerning the methods of mineral exploration, geochemical techniques, assessment of prospecting results, and the minimization of environmental impact.

Hand-panning samples, geochemical prospecting in the Mongolian Altay.

Sampling sands at shifting desert sand dunes, Swakopmund – Walvis Bay area, Namibia.



Abandoned open pit of the Chambishi ore deposit, Zambian Copperbelt.

The Landsat image (5/7:3/1:4/3) used for the study of hydrothermal associations, Mongolian Altay.

Emerald porphyroblast in phlogopite rock, Kafubu mine, Zambia.

Projects

Emerald mineralization in the Kafubu area, Zambia (2001)

Evaluation of energy potential of black shales in Burkina Faso and the environmental impacts of their combustion (2001–2002)

Evaluation of selected glassmaking raw material resources in Namibia (2001–2003)

Lithological, structural and geochemical studies of mineralization in the Zambian part of Copperbelt, and the impacts of old mining on environment (2001–2003)

Evaluation of gold resources in waste material after artisanal mining in Burkina Faso, and their potential for further economical use (2003–2005)

Glassmaking raw material resources in Namibia

In accordance with the discussion held by His Excellency Dr. Sam Nujoma, President of the Republic of Namibia and the Government of the Czech Republic in 1999, the two governments agreed to cooperate in a geological field survey toward building up a glass industry in Namibia. The follow-up project "Evaluation of selected glassmaking raw material resources in Namibia" was carried out by a team comprised of employees of the Czech Geological Survey, Sklopísek Střeleč Ltd., EXIMOS, the ÚNS - Výzkum Company, Ltd. of Kutná Hora, and Brita Trade Company, Ltd. of Hradec Králové.

The major objectives of the project were to carry out a geological assessment of quartz and other raw materials necessary for glass-batch preparation in Namibia and undertaking of test meltings. However, an assessment of all known occurrences of vein quartz, pegmatite quartz, and aeolian sands in Namibia determined that the quartz reserves were either of insufficient quantity or of too low quality.

During the 2001 field campaign, a promising deposit of hydrothermal quartz was discovered approximately 40 km west of Rehoboth (Choaberib Farm). The deposit is comprised of four distinct vein-like bodies and another five quartz blows 10 m or more in thickness. Seven individual outcrops can be traced on the surface for a distance of more than 200 m. A total economic reserves of 9.7 million tons of massive milky vein quartz were calculated down to a depth of 25 meters. Samples showed slightly increased contents of Co (6–9 ppm) after electromagnetic beneficiation.

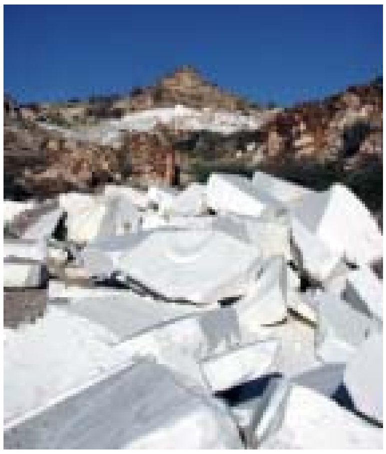
A large deposit of metasandstone was discovered in the vicinity of Rehoboth formed by sheet-like bodies. The total inferred reserves of all quartzite bodies (>20 m thick) can be estimated at 6.8 million tons (99.26 wt. % SiO_2, 0.4 wt. % Al_2O_3, 0.035 wt. % Fe_2O_3, and 0.03 wt. % TiO_2).

Carbonate raw materials for the glass industry were assessed in five regions of Namibia. White dolomite marbles from the White Rhino quarry and from the Otjiwarongo quarry were found to be the most suitable, where even – the waste and unsellable blocks can be used. The dolomite marble from the Okongava deposit can be considered a suitable material for the production of colourless sheet/float glass and colourless or container glass.

The test meltings of siliceous material from the Choaberib locality, together with dolomite marble from the White Rhino deposit, revealed that these materials are suitable for the production of high-quality colour parison (low-cost coloured crystal glass and high-lead crystal glass). The experimental production of blue decorative glass was also successfully carried out at Kras Glass Ltd, Nový Bor. The hydrothermal quartz from the Choaberib Farm was recommended to the Namibian Ministry of Mines and Mineral Development for considering small-scale manufacture of decorative glass at this locality.

The experiments confirmed that the metasandstone from Rehoboth together with Okongawa dolomite marble are suitable for the production of coloured container glass (green-coloured glass for wine bottles, brown-coloured glass for beer bottles). The Goverment of Namibia instructed the Geological Survey of Namibia and the Ministry of Trade and Industry to carry out a feasibility study for the establishment of a small glass factory in Rehoboth to produce container glass.

A general view of quartzites of the Swakop Group exposed SW of Rehoboth; one of the quartzite bodies (picture left).



Waste material from quarrying of dolomite marble block in the White Rhino quarry, Karibib region.

Raw glass blocks from melting experiments. Choaberib quartz: 5 – lead crystal glass; Rehoboth metasandstones: 6 – green container glass, 8 – light violet container glass, 9 – brown container glass, 10 – flat glass.

Rehoboth west – a newly discovered locality of quartz veins representing suitable material for the production of colourless sheet/float glass and colourless container glass.

Gold sources in the waste material from artisanal mining in Burkina Faso

Burkina Faso is one of the developing countries in western Africa, and only during past the 10 years has it become classified by leading world financial institutions as a country with prospective mineral resources (especially gold). Gold has mostly been primitively mined and processed at many places. At present, around 150,000 individuals, of which around 40 % are female, are involved in seasonal gold mining. The mining, in combination with agricultural activities, represents one of the most important sources of income for the people living in the countryside.

The Czech technical assistance program on the "Evaluation of gold sources in waste material after artisanal exploitation in Burkina Faso and possibilities of their further economical use" (2003–2005) has been jointly carried out with BUMIGEB. The project is focused on the technical-economical evaluation of gold production potential in the waste material from the mining and processing of gold ores in selected regions. This would contribute to their industrial development, and thus decrease the level of poverty. The project will be sustained by the transfer of "know-how" through organizing workshops and field training.

Extraction of gold using a primitive sluice.

Manual crushing of gold ore.

Black shales as a possible source of energy in Burkina Faso

A lack of energy resources in Burkina Faso results in the highest prices of energy on the entire African continent. This fact limits economic development and results in many environmental problems. The deforestation and desertification in Burkina Faso have created a situation in which the original vegetation now grows only in the national parks.

The main goal of the project, carried out by CGS and University in Ouagadougou was the evaluation of black shales as a possible source of energy. Our studies showed that the following three different groups of black shales can be distinguished within the Proterozoic greenstone belts in Burkina Faso: (1) Low-degree metamorphosed black shales that could be considered as a prosperous raw material for combustion, (2) High-degree metamorphosed black shales that could be considered as a prosperous source of "amorphous" graphite and (3) Transitional group of black shales (medium-degree metamorphosed).

It was documented that based on technological properties low-degree metamorphosed black shales in the Kaya region correspond to antracite and/or meta-antracite. These facies could be after mixing of powdered black shales with waste biomass and subsequent pelletizing combusted in portable furnaces similarly as in the southern China.

Detailed geological and technological studies showed that the black shales at the Gan locality represent an important source of graphite for the foundry plants.

Primitive gold mining and "wind-washing" in northern Burkina Faso.

Outcrop of black shales at the Tougan locality, NW Burkina Faso.

The documention of a trench at the Gan locality; the local black shales can be registered as a source of amorphous graphite suitable for the foundry industry.

Disscussing a geological profile at Gan field, Burkina Faso.

Gold extracted from waste material using gravitational methods.

Emerald mineralization in the Kafubu area, Zambia

This project conducted by the CGS in 2001 was undertaken on the request of the Zambian Ministry of Mines and Minerals Development, Lusaka. Emerald is by far the most important gemstone mined in the country and the Zambian government is looking for ways to boost the efficiency of its emerald mining sector. In the past two decades, Zambia has become a significant gem-producing country. The Kafubu area, being believed to produce up to 20 per cent of the world emerald production, represents an important economic potential for Zambia.

The major project objectives involved the study of the geological setting, and gathering all key information and data regarding the origin and distribution of emerald mineralization in the Kafubu – Ndola Rural Restricted area. Besides the paragenetic-geochemical features of the mineral assemblages this study provided the first quantitative geochemical, petrological and mineralogical data on the major rock types and minerals in the Kafubu area.

Highly magnesian talc-chlorite ± actinolite ± magnetite metabasites, identified as metamorphosed Cr-rich komatiites, that host the emerald mineralization provided the chromium necessary for the crystallization of emeralds. Emerald-bearing phlogopite schists are confined to the contacts between quartz-tourmaline veins and magnesian metabasites. The Li-Cs-Ta quartz-feldspar pegmatites are commonly enriched in beryllium and Ta-Nb minerals. The fluorine- and boron-rich fluids deposited quartz-tourmaline veins and altered adjacent metabasites into the phlogopite schists. Data on pegmatite occurrences point to the existence of a single major Kafubu pegmatite field with the closure of the system occurring within the interval of 452-447 Ma ($^{40}K/^{40}Ar$ dating of muscovite).

Emerald samples from the Kafubu area range in intensity of colour from light green to dark green, having many inclusions and being moderately fractured. Electron microprobe analyses of Kafubu emeralds show contents of 0.17–0.59 wt. % Cr_2O_3. For the first time, data on fluid inclusions in beryl/emerald, tourmaline and quartz were obtained for these deposits and the mineralization pT conditions were estimated.

The significant features governing emerald mineralization have been recognized, and recommendations for exploration have been presented. These recommendations involve assistance, information, and advice to the Zambian government in planning future policies for attracting private investment, as the potential for new emerald occurrences in the Kafubu area still remains very high.

Bulletin of Geosciences, 79, 1, 2004 (www.geology.cz).

Gerntina mine, Zambia

An intensively kaolinized pegmatite vein, Fwaya-Fwaya – extension (F10) mine.

Emerald aggregates grown in the parent rock, Fwaya-Fwaya mine.

Emerald crystals in laterite from Kamakanga Old Pit.

Zoned tourmaline crystals in phlogopite rock, Kafubu mine.

Emerald-tourmaline aggregate from Kafubu area, Zambia (the sample is 4 cm long).

Documentation of the boreholes drilled by Kamakanga Ltd. within emerald-parent rocks, Kamakanga mine.

Mine face with beryl mineralization, Fibolele mine, Kafubu area.

Geochemistry & Environmental Impact

The Impacts of Ore Mining & Processing
Industrial Pollution Risk Assessment
Environmental Management

In developing countries, relatively little attention is paid to the impact of mining and ore processing on the environment. This is due mostly to poverty and a low level of public awareness. As the majority of the population in mining districts depends on natural resources for their livelihood, environmental problems can seriously undermine the future of these people. An important part of the development aid-funded projects is therefore to teach the local population how to balance the creation of wealth with the quality of life.

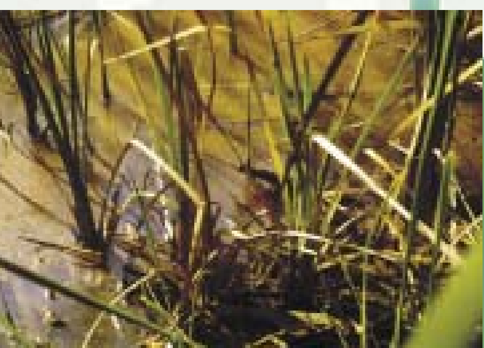
The ongoing CGS projects include the regional-environmental mapping of heavily polluted areas, the reconnaissance of “hot spots” of industrial pollution, and monitoring, modelling, and predicting the extent of anthropogenic impact to the air, water, soil, agricultural production, and human health quality. Our findings can be used by the state administration toward coordinating environmental management, promoting public awareness, and minimizing environmental deterioration in areas affected by mining. The local administrations are encouraged to use the results of the development assistance projects as a foundation for informed decision-making at all levels, from the allocating of land-use zones in town planning to the sustainable development and use of raw materials.

The effects of sulphur dioxide emission on buildings in the Kankoyo Township in Mufulira is documented by the rapid corrosion of steel roofs and discoloration of wall paintings.

Dry beach of the abandoned tailing impoundment located SW of the Mufulira impoundments area.

Sampling of sub-surface soil using a soil probe during the geochemical mapping campaign in the Zambian Copperbelt.

Sampling water of the Chambeshi River, which drains the Chambishi-South tailing. Whitish precipitates of carbonate indicate the effect of liming of slimes.



Coatings of iron hydroxides on a small stream near the Chambishi-N tailing impoundment dam, Zambia.

Projects

Impact Assessment of Mining of Beryl Mineralisation on the Environment in the Kafubu Area; Problems and Solutions (2003)

Evaluation of the impact of copper and cobalt mining in the Zambian Copperbelt to environment and the proposal of monitoring system of contamination by heavy metals and sulphur (2002)

Evaluation of the environmental impact of copper and cobalt mining in the Zambian Copperbelt

The environmental geochemical mapping of stream sediments, soils, and agricultural products was carried out to determine the extent of industrial pollution in the area north of Kitwe, an area heavily affected by mining and processing of copper and cobalt ores. The mapping was carried out by a team from the Czech Geological Survey, the Geological Survey of Zambia and Zambian University, School of Mines in the year 2002.

The aim of the project was to analyse the degree of contamination of stream sediments, soils and agricultural plants with toxic metals in a selected model area, toward determining the effects of mining on the environment and to initiate a long-term monitoring scheme of stream sediment and soil contamination. To achieve this aim, the geochemical evaluation of essential types of materials deposited in spoil piles, in tailing impoundments and slag heaps, and the study of mechanisms of mobilization of toxic metals from the deposited anthropogenic materials, were also carried out.

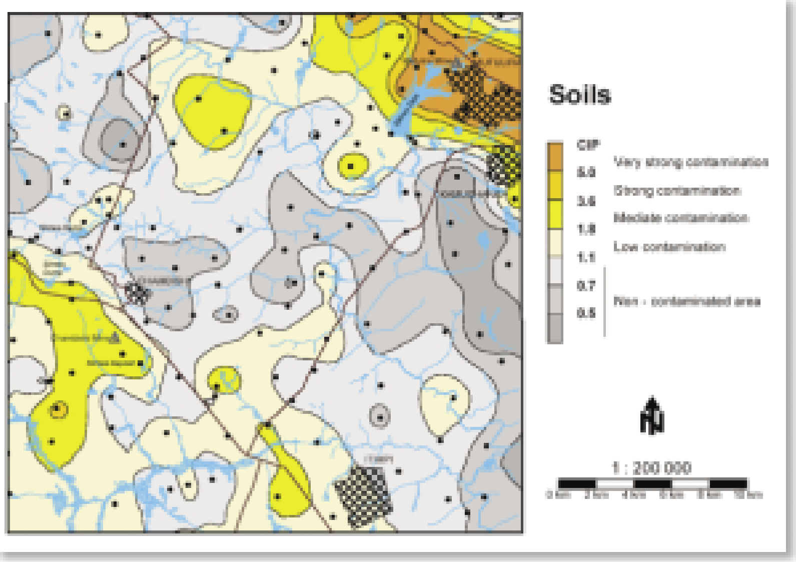
Two mined ore deposits (Mufulira and Chambishi) and the Mufulira smelter and refinery lie within the area of the environmental geochemical study (scale 1:50,000; the total area of 429 km^2). It was found that the main sources of contamination in the studied area are: (1) mining waters and seepage through the tailing dams, (2) wash-out of the fine-grained material from spoil banks, and (3) airborne particles from the beaches of tailing impoundments, crushers and the Mufulira smelter. Washed-out, fine-grained material from spoil heaps, sampled from the bottom of the heaps contain up to 4 ppm As, 40 ppm Co, and 3200 ppm Cu. Heavy metals in airborne particles are bound mostly to the very fine sulphide fraction (pyrite, chalcopyrite, covelline, chalcocite and carrollite). Strong anthropogenic contamination by Co, Cu, Cr, Hg, Mo, and Se was detected also locally in the stream sediments. In the Mufulira area, increased amounts of heavy metals were recorded in almost all collected agricultural products.

It was established that the degree of industrial contamination may be best expressed using the Coefficient of Industrial Pollution (CIP), which is the sum of the concentrations of selected metals in the topsoil at individual sampling point divided by the median values of the same metals in the topsoils of the whole region.

This project has documented that the results obtained from the geochemical mapping can be used to characterize the extent of contamination, even in areas with multiple geological and anthropogenic sources of heavy metals. The results presented in the form of maps of CIP values can be used in allocating suitable land-use zones in town planning.

Environmental Assessment of the Mining of Beryl Mineralisation in the Kafubu Area, Zambia

In 2003, the major objectives of this project for evaluating the emerald mineralisation in the Kafubu area, Zambia, were to gather key data relating to the influence of the current, and old mining activities on the environment. The project was aimed at ascertaining and describing the typical cycle of mining operations in the Kafubu area, to define a list of priority impacts on the environment, and evaluating mining impact on the sustainable, resource-based development of the Kafubu area. It covered items such as deforestation, vegetation removal, damage of topsoil, dumping of waste, habitat disturbance, reduction of biodiversity, fauna and flora habitat loss, degradation of land, soil erosion, siltation of streams, and the contamination of soil and water systems.



Using the Coefficient of Industrial Pollution values for the surface layer of soils, three main areas of the anthropogenic contamination have been identified in the Mufulira – Chambishi area.

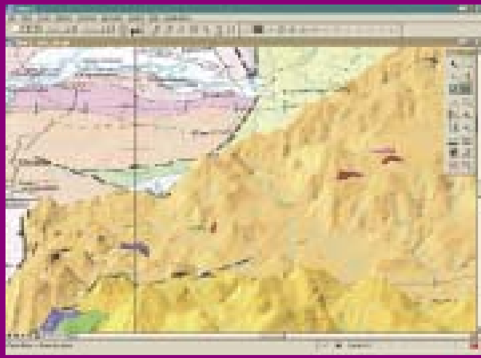
Increased amounts of heavy metals in agricultural products in the Mufulira area, endanger local farmes.

Cluster of needle-like particles from the Zambian Mufulira smelter. SEM.

Kafubu mine, a new active open pit of the Kamakanga Co. producing emeralds, Zambia.

Management & Delivery of Geodata

Support of Development Assistance Projects
Geographical Information Systems
Remote Sensing Analyses
Digital Map Production

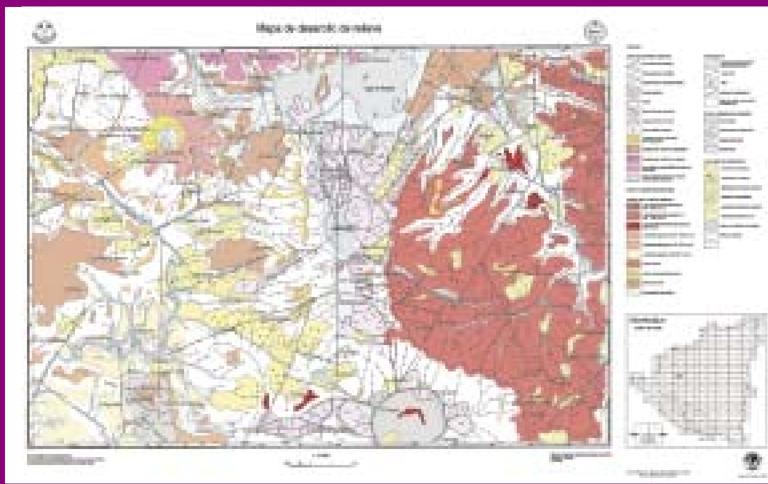


The 3D model of the Luwumbu River area in the NE Zambia, view from SW.

The CGS has been responsible for acquiring, storing, and analyzing geoscience data and information since its foundation. We have developed a data management system for the effective delivery of the geodata being built up and maintained by the CGS Division of Informatics.

The uniform geological information system of the CGS, based on a 3-layer architecture, consists of:

- Central Data Warehouse
- Metadata Information System
- Information Portal (www.geology.cz)
- Internet Map server

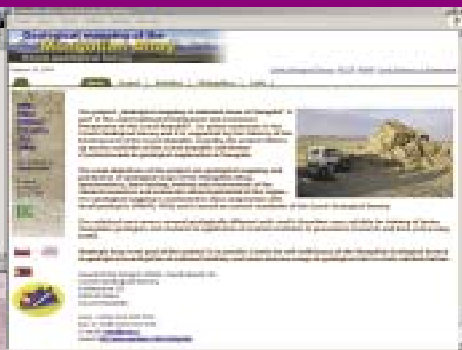


The digital 1:50,000 map of the land relief development, Jinotega, Nicaragua.

Modern information technologies are routinely used within the CGS to solve geological problems using methods such as geographic information systems (GIS), 3D modeling, data querying, and spatial analyses. Specialists from the Department of Information Systems are either fully responsible or provide consultant services for the digital processing and publishing of CGS projects.

Furthermore, the latest available technological advances allow geologists and other specialists to utilize advanced methods, such as the use of remote sensing during geological and thematic mapping.

Entrance window of the Information Portal of the Czech Geological Survey.



WWW pages of the Mongolian Project.

www.geology.cz

Printing the digital version of a map on the plotter, the IT Centre, Prague-Klárov.

A lecture in development and management of GIS for the employees of the Geological Information Center, MRAM, Ulaanbaatar.

The CGS IT team received a prestigious Special Achievement in GIS Award at the 24th Annual ESRI User Conference, 2004, San Diego.

Technical support of the projects

The CGS development assistance projects have the full support of the CGS IT specialists, who usually participate in the planning phase, in the assessment of data, and in the compilation of the projects' results.

Project support consists mainly in:

- starting-up the projects
- the preparation and transformation of geographical field maps
- collecting, managing & delivering geodata in GIS format
- spacial data processing
- vectorization of geological and thematic maps
- production of digital maps (prints, CD/DVDs, Internet)
- 3D modelling of mapped areas
- lecturing & training the local staff in the use of geographical information systems and geoscience data

Geographical Information Systems (GIS)

Most of geological data is spatially oriented; the implementation of GIS technology therefore plays an important role in developing a complete geological information infrastructure for the CGS. GIS technology is applied in three major fields:

- the development and management of corporate GIS (digital geological maps and related data sources)
- the use of GIS within CGS projects
- GIS solutions for local surveys and authorities

A digitized geological sketch of the volcanoes in Ometepe Island, Nicaragua.

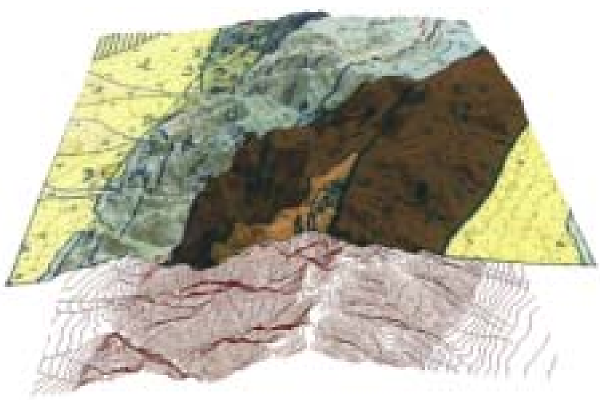
Digital map production

Map production using digital methods began at the CGS in the mid-1990s. Following the introduction of GIS methods to our map publishing, a Digital Map Production System was created. This system has also been applied to the publishing of geological maps of compiled within the Development Assistance Program projects, for example in Nicaragua and Zambia.

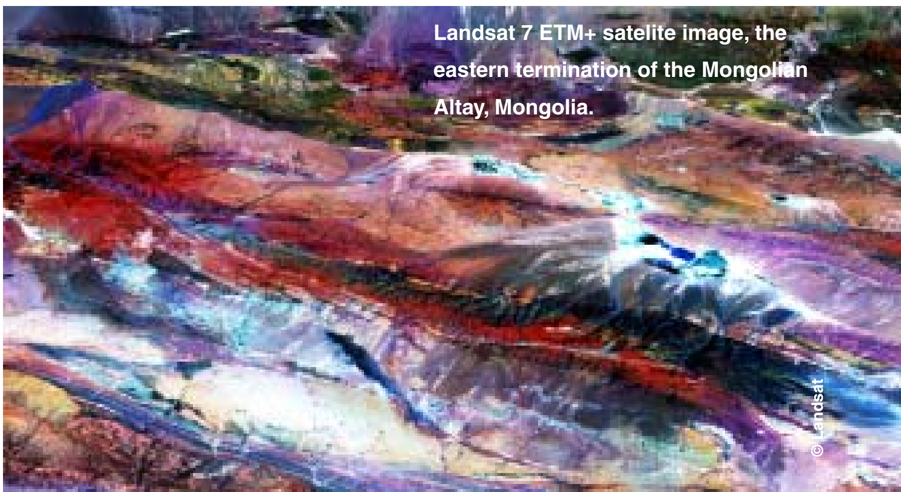
Spacial data processing

Geographic Information Systems (GIS) and Remote Sensing have become a integral components of numerous earth resource applications for such activities as geological mapping, structural analysis, mineral exploration, geomorphological interpretation, and geohazard mapping. The specific and extreme natural conditions in Mongolia, El Salvador or Peru, such as lack of vegetation and rocks exposure, enhance the utilization of such methods.

The 3D slope analyses model and fault interpretation, the Guazapa volcanic complex, El Salvador.



The 3D model of the Mongolian Altay area, sheet L-47-101 G.



Landsat 7 ETM+ satelite image, the eastern termination of the Mongolian Altay, Mongolia.

Laboratory Services & Research

Inorganic Analyses of Rocks, Soils and Waters
Analyses of Gases, Crude Oil & Organic Matter
Special Methods For Geology and Environment

The CGS Central Laboratory has long standing experience in the inorganic analysis of rocks, soils, sediments, mineral raw materials and surface and rain water. The Accredited Laboratory at Prague-Barrandov supplies the chemical analyses of **solid samples** performed by:

- Perkin-Elmer flame AA spectrometers 3100, AAnalyst 100 and 4000 with hydride generation unit
- Iris Advantage Thermo Jarell Ash emission spectrometer with inductively coupled plasma
- Perkin-Elmer Hitachi 200 and Lambda 10 spectrophotometers
- mercury analyser AMA 254
- C and S analyser of Eltra CS 500
- CO_2 analyser (Strohlein)
- RL wave dispersed X-ray spectrometer 9400 Advant XP
- automatic volumetric apparatus pX-meter (Radiometer)
- platinum metals
- modern unit for preparing deionized water

Water analyses are performed by:

- mercury analyser AMA 254, pX meter, conductometer
- Perkin-Elmer Hitachi 200 and Lambda 10 absorption photometers
- Shimadzu liquid chromatograph with UV detection
- Perkin-Elmer 3100 and AAnalyst 100 flame AA spectrometers
- Perkin-Elmer 4100AA spectrometer with electrothermic atomization
- IRIS Advantage, Thermo Jarell Ash emission spectrometer with inductively coupled plasma

The Laboratory of Organic Geochemistry at the Brno Branch Office performs chemical analyses of organic matter in rocks, crude oils, gases and organic pollutants in sediments, soils, water and wastes. Our analytical results are applied to organic geochemistry, environmental organic chemistry, and in monitoring environmental pollution. Analytical methods and instrumentation:

- elemental analysis of carbon, sulphur and chlorine (TC, TOC, TIC, DOC, AOX, EOX) by Eltra (Metalyt CS), Stroehlein (7020Cl) & ThermoEuroglas (TOC 1200)
- gas chromatographs Agilent Technologies (AT) 6890 and 5890 with FID, ECD, NPD and TCD detectors for analysis of gases, hydrocarbons and organic pollutants
- headspace analyzer Tekmar Dohrmann 7050HT for determination of volatile organic compounds
- gas chromatography / mass spectrometry detection AT 6890 GC / AT 5973 MSD for analysis of biomarkers in rocks and oils and organic pollutants in environmental samples
- high-performance liquid chromatography with UV/VIS and fluorescence detection AT 1100 for determination of polycyclic aromatic compounds & other pollutants
- infrared spectrometry (Perkin-Elmer 783) for qualitative analysis and determination of non-polar extractable compounds
- isolation and preparative facility for organic analysis by Dionex (ASE), Foss (Tecator Soxtec) and Zymark (TurboVap)
- optical analysis of organic matter in rocks (kerogen description, vitrinite reflectance and maceral description)

The Perkin-Elmer AAnalyst 100 flame AA spectrometer analyses cations in waters and solid samples.

IRIS Advantage Thermo Jarell Ash emission spectrometer: main and trace elements in waters, REE in solid samples.

Trace elements in solid materials are measured by the wave dispersed X-ray spectrometer 9400 Advant XP (ARL).

Gas chromatographs GC AT 6890 and GC/MSD AT 6890/AT 5973 for analysis of organic pollutants.

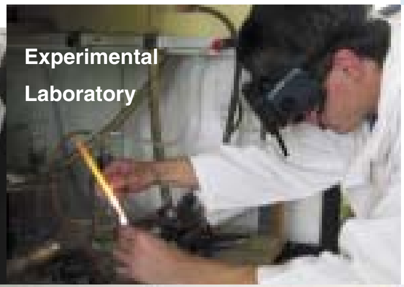
The CGS Central Laboratory in Prague and Laboratory of Organic Geochemistry in Brno have Certificates of Accreditation as testing laboratories in accordance with standard EN ISO/IEC 17025; their activities also comply with ISO 9002.

Laboratories of the geochemistry departments

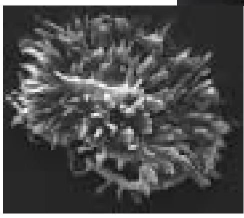
The research activities of these departments encompass a wide spectrum within the earth sciences, from mineralogy and petrochemistry, to the geochemistry of the atmosphere, hydrosphere and terrasphere, and even interdisciplinary environmental sciences such as biogeochemistry, medical geology, plant and soil ecology, and global change.

Laboratory of Mineralogy and Special Methods

- **X-ray Diffraction Facility.** This laboratory, equipped with a Philips X'pert System powder diffractometer, has participated in mineralogical, geochemical, and environmental projects. Our work has included qualitative and quantitative phase analysis, crystal structure refinement, description of new natural phases, and the study of extraterrestrial minerals.
- **Mineral Separations Facility**
- **Thin Sections Facility**
- **Optical Microscope Facility**
- **Fluid Inclusions Facility**
- **X-ray Microanalysis Facility (LAREM).** LAREM is equipped with two independent analytical systems: a LINK ISIS 300 energy-dispersion (ED) system with an ultra-thin window, and a Microspec wave-dispersive system. The laboratory has performed over 100,000 quantitative chemical analyses.
- **The Laboratory of Experimental Petrology** studies phase relationships and synthesizes mineral phases.
- **The Micropaleontological Facility** prepares microfossils for examination under the CS 3200 scanning electron microscope.



Experimental Laboratory



Polysynthetic compound crystal intergrowths of smythite, Jáchymov.

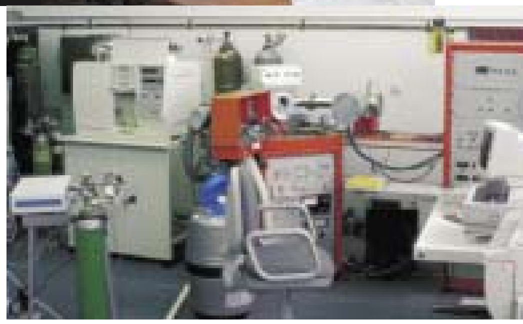
Microspore *Raistrickia* sp., Upper Carboniferous, Radčice at Plzeň.

The Laboratory of Stable Isotopes

is equipped with two mass spectrometers, a Finnigan MAT 251 and a Geo 20-20. Routinely available analyses include: the determination of ^{13}C and ^{18}O in carbonates; ^{2}H and ^{18}O in waters, ^{13}C in solid, liquid and gaseous organic materials; ^{15}N in organic materials and solutions; ^{18}O in sulfates; and ^{34}S in sulfides and sulfates. The laboratory has participated in several international calibration exercises (sulfur and carbon standards).

The Laboratory of Radiogenic Isotopes

studies the distribution of radiogenic isotopes, principally of Sr and Nd, in natural environments. The chemical separations are carried out by ion-exchange techniques in the Ultra Clean Lab. LARIZ is equipped with a Finnigan MAT 262 thermal ionization mass spectrometer (TIMS).

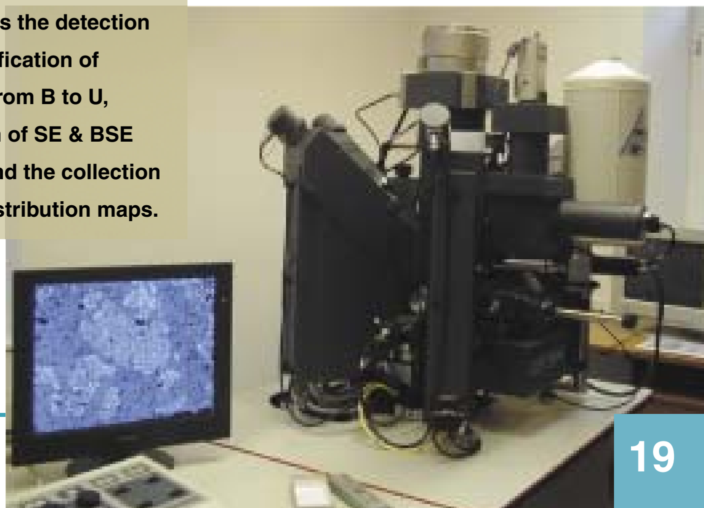


The Finnigan MAT 251 in the Stable Isotope Laboratory.

The Radiogenic Isotope Laboratory is equipped with a Finnigan MAT 262 mass spectrometer.

The X-ray Microanalysis Laboratory has performed over 100,000 quantitative chemical analyses.

Static headspace autosampler Tekmar 7050HT for determination of volatile organic compounds.



The CAMECA SX-100 electron microprobe, at the joint laboratory of Masaryk University, Brno & the CGS, allows the detection and quantification of elements from B to U, acquisition of SE & BSE imagies, and the collection of X-ray distribution maps.

Earth Science Training & Education

Geochemical Prospecting Methods
Methods of Geological and Thematic Mapping
Collecting and Applying Geodata

Education and earth science training are an integral part of all development assistance projects carried out by the Czech Geological Survey.

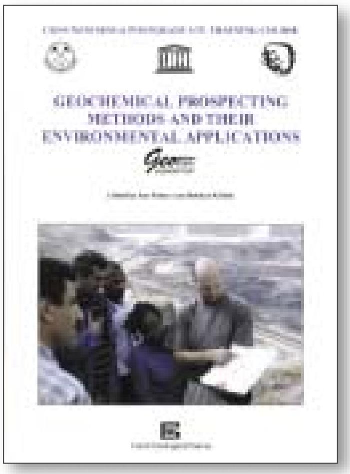
GEOCHIM

Every year, CGS organizes a certified postgraduate training course (together with UNESCO and SGA), that aims at providing knowledge about the widely used geochemical methods for ore deposit prospecting and the solution of environmental problems. Lectures, seminars, and practical training also include subjects such as environmental geochemistry, analytical methods and computer modelling of prospecting and environmental data. From 1999 to 2004 six courses were organized and 81 participants, representing 31 African, Asian and East Europian countries, successfully passed through the GEOCHIM course.

http://www.geology.cz/host/geochim.htm

A geological excursion for the students of Mongolian University of Science & Technology, Ulaanbaatar, in Mongolian Altay, 2004.

Lectures in economic geology, petrology, and regional geology given at the Geological Department, MUST, Ulaanbaatar.



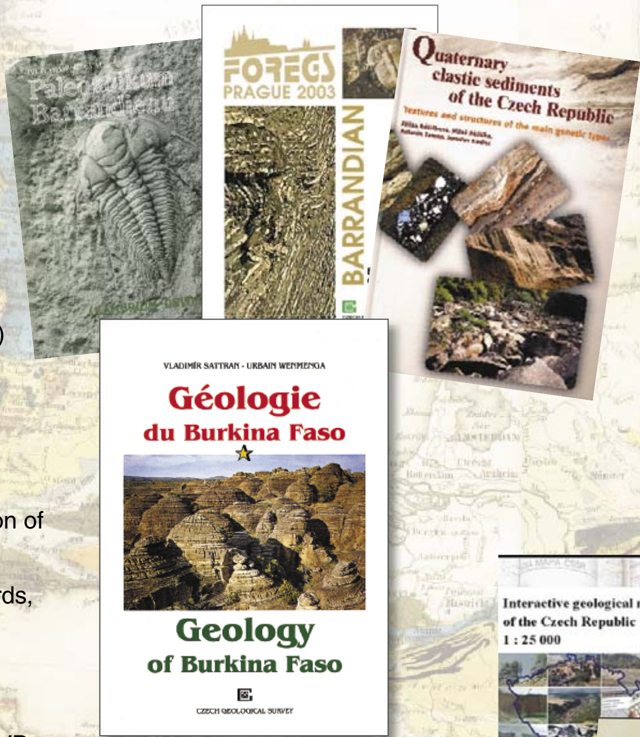
The textbook prepared for the purpose of the GEOCHIM Postraduate Training Course.

The photos in the lower half of this page document the GEOCHIM training activities of 2002, 2003 and 2004.

Publications

Since its establishment in 1919, the Czech Geological Survey has been publishing geological studies and maps:

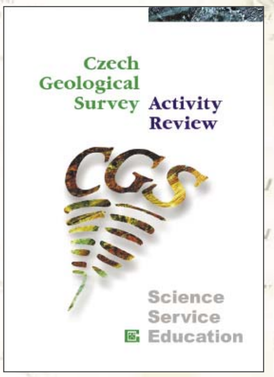
- geological and applied maps with explanatory texts
- regional/geological publications, monographs and methodological handbooks
- series of thematically oriented publications (CGS Special Papers, Transactions of CGS, Library of CGS)
- geoscience periodicals (Bulletin of Geosciences, Journal of Geological Sciences, Reports on Geological Research)
- publications dealing with the protection of the geological environment
- popular publications, posters, postcards, hiking geological maps
- the proceedings of national and international conferences
- specialized maps on CD-ROM and DVD (Geological Maps of Europe, GEOCR 500, Radon Risk, Interactive Geological Maps 1:25,000).



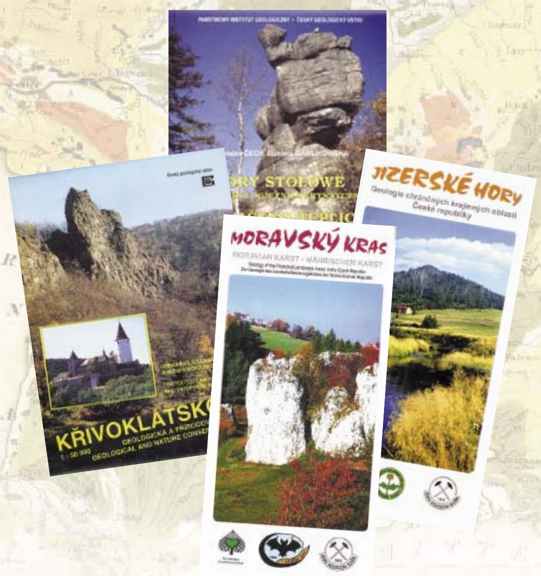
A monography compiled within the CGS Development Assistance Project in Burkina Faso.

Bulletin of Geosciences provides free on-line access to abstracts and full papers (www.geology.cz).

Geological & thematic maps in digital format (CD/DVD-ROM).



Communication documents are available on request at the e-mail address info@cgu.cz *or* can be downloaded from the CGS Portal: www.geology.cz.



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