ACADEMY OF SCIENCES OF THE CZECH REPUBLIC

Geophysical Institute Prague

Report
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Academy of Sciences of the Czech Republic (http://www.cas.cz)

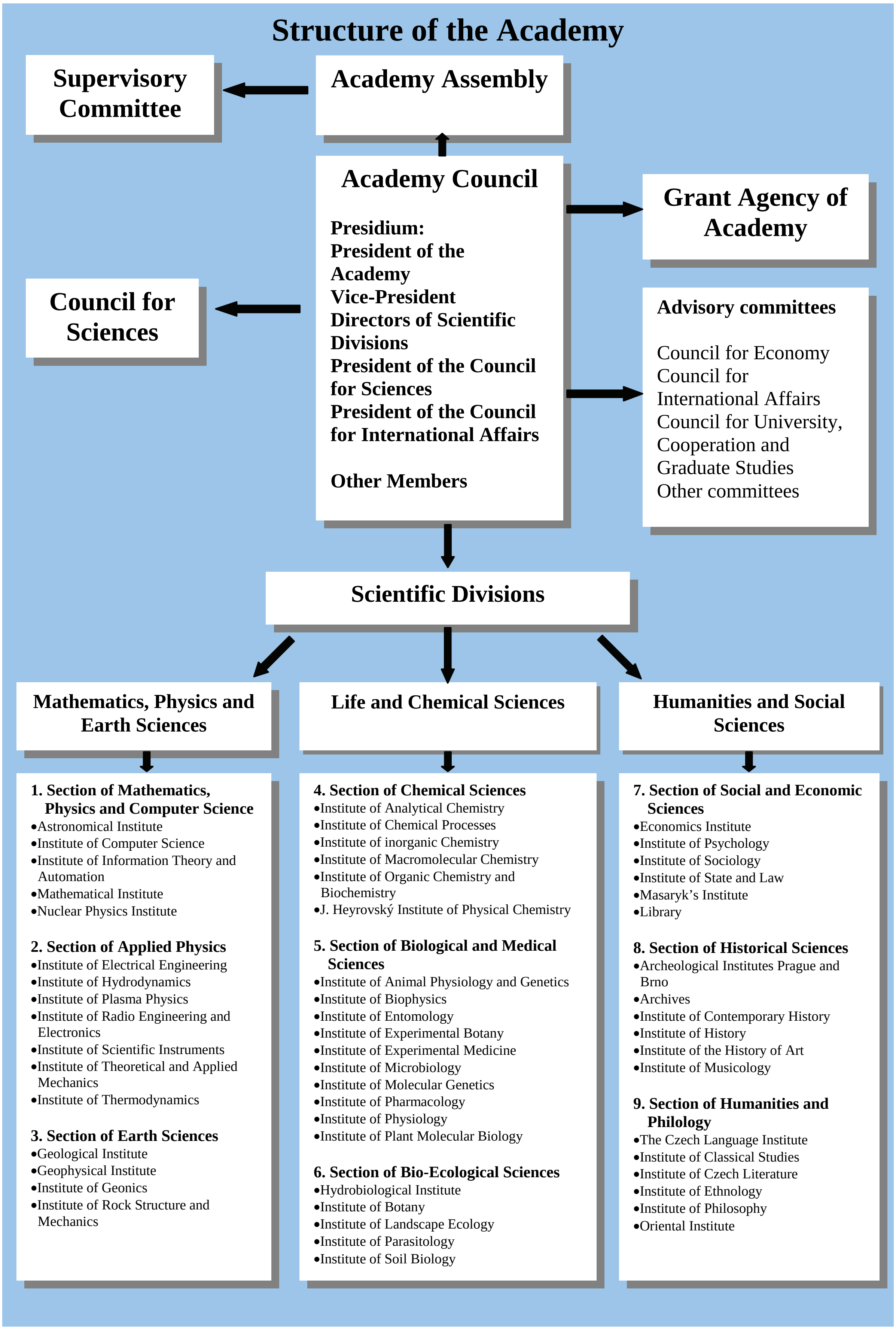
The Academy of Sciences of the Czech Republic was established in 1992 as the Czech successor of the former Czechoslovak Academy of Sciences. It is structured as a network of 59 research institutes and five supporting institutions, and staffed by 6500 employees, approximately one-half of whom are university-trained scientists and Ph.D. researchers.

The chief objective of the Academy is to carry out fundamental and strategic applied research in natural, technical, and social sciences as well as the humanities. This research is distinguished by adherence to high scientific standards whether it is interdisciplinary in nature or highly specialised. The Academy's institutes are involved in education by supervising Ph.D. theses, by providing post-graduate courses to young researchers and by lecturing at universities. The Academy promotes contacts with both the applied research and industrial sectors in order to foster technology transfer and exploitation of scientific knowledge.

The Academy of Sciences is financed primarily from the State Budget. The total financial resources are divided among the institutes according to the evaluation of their scientific results. Further sources of income include funds acquired from grant agencies in competitions of scientific projects. The Academy has also its own grant agency to support small-scale projects.

The present-day Academy of Sciences of the Czech Republic builds upon the tradition of the former Czechoslovak Academy of Sciences as well as upon its many predecessors. The first society that brought together scientists in the Czech lands was Societas Incognitas, active between 1746 and 1751. The oldest, truly long-existing (1773-1952) learned society was the Bohemian Learned Society, which encompassed the natural sciences and humanities. Its founders included Czech philologist Josef Dobrovský (1753-1829), the historian Gelasius Dobner (1719-1790) and the mathematician and founder of the Prague University observatory Joseph Stepling (1716-1778). In later years, Czech historian František Palacký led the Society. As early as 1861, the famous biologist Jan Evangelista Purkyně (1787-1869) proposed in his work 'Academia' that a self-governing, non-university research institution be formed which would incorporate scientific institutes representing the main branches of science of that time. This vision of an institution devoted to interdisciplinary research was very close to the concept and structure of today's Academy of Sciences.

All research institutes are grouped according to the objective of their research into nine sections. Each section contains from 5 to 10 institutes. One of the sections is the Section of Earth Sciences, consisting of five institutes including the Geophysical Institute. This Section of Earth Sciences has a total of 470 employees, of which 250 are graduate research workers.



Structure of the Academy
Supervisory Committee
Academy Assembly
Academy Council
Presidium:
President of the Academy
Vice-President
Directors of Scientific Divisions
President of the Council for Sciences
President of the Council for International Affairs
Other Members
Grant Agency of Academy
Council for Sciences
Advisory committees
Council for Economy
Council for International Affairs
Council for University, Cooperation and Graduate Studies
Other committees
Scientific Divisions
Mathematics, Physics and Earth Sciences
Life and Chemical Sciences
Humanities and Social Sciences
1. Section of Mathematics, Physics and Computer Science
•Astronomical Institute
•Institute of Computer Science
•Institute of Information Theory and Automation
•Mathematical Institute
•Nuclear Physics Institute
2. Section of Applied Physics
•Institute of Electrical Engineering
•Institute of Hydrodynamics
•Institute of Plasma Physics
•Institute of Radio Engineering and Electronics
•Institute of Scientific Instruments
•Institute of Theoretical and Applied Mechanics
•Institute of Thermodynamics
3. Section of Earth Sciences
•Geological Institute
•Geophysical Institute
•Institute of Geonics
•Institute of Rock Structure and Mechanics
4. Section of Chemical Sciences
•Institute of Analytical Chemistry
•Institute of Chemical Processes
•Institute of inorganic Chemistry
•Institute of Macromolecular Chemistry
•Institute of Organic Chemistry and Biochemistry
•J. Heyrovský Institute of Physical Chemistry
5. Section of Biological and Medical Sciences
•Institute of Animal Physiology and Genetics
•Institute of Biophysics
•Institute of Entomology
•Institute of Experimental Botany
•Institute of Experimental Medicine
•Institute of Microbiology
•Institute of Molecular Genetics
•Institute of Pharmacology
•Institute of Physiology
•Institute of Plant Molecular Biology
6. Section of Bio-Ecological Sciences
•Hydrobiological Institute
•Institute of Botany
•Institute of Landscape Ecology
•Institute of Parasitology
•Institute of Soil Biology
7. Section of Social and Economic Sciences
•Economics Institute
•Institute of Psychology
•Institute of Sociology
•Institute of State and Law
•Masaryk's Institute
•Library
8. Section of Historical Sciences
•Archeological Institutes Prague and Brno
•Archives
•Institute of Contemporary History
•Institute of History
•Institute of the History of Art
•Institute of Musicology
9. Section of Humanities and Philology
•The Czech Language Institute
•Institute of Classical Studies
•Institute of Czech Literature
•Institute of Ethnology
•Institute of Philosophy
•Oriental Institute

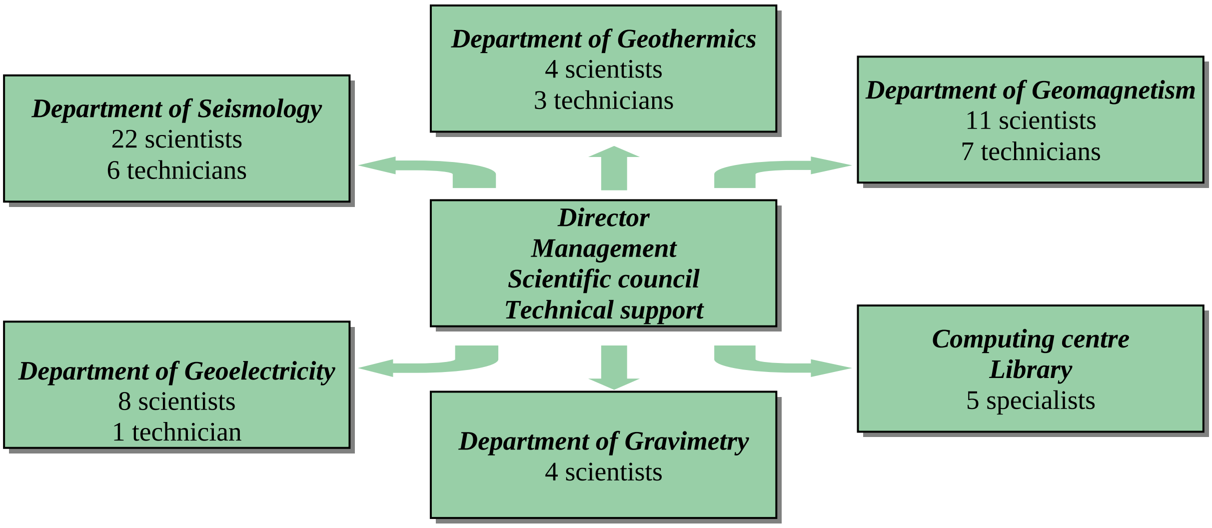
Geophysical Institute (http://www.ig.cas.cz)

The Geophysical Institute of the Academy of Sciences of the Czech Republic follows a considerably long tradition connected with interest in the natural sciences. An abrupt increase in demand for more scientific knowledge in the natural sciences is expected to be caused by extensive exploitation of minerals during the Middle-Ages. There is well-documented historical mining activity in the areas of Kutná Hora, Jihlava and Příbram, among others. Great scientific progress has been achieved in geology and mineralogy. Charles University in Prague (founded in 1348 by the emperor Charles IV.) was the education centre within the former Central Europe, natural sciences were taught there since 1622. Actual geophysical measurements and development started later, however. Starting with the year 1771, systematic measurements of the surface air temperature have been made in the Jesuit Academy in the Clementinum College in Prague. Also the sequence of regular precipitation measurement began in 1804 as the oldest one in Central Europe. Geomagnetic measurement was started here some time later and, in 1839, Carl Kreil put one of the oldest geomagnetic observatories in the world into operation. The first relative pendulum measurements of gravity were carried out in the mines of Příbram in 1882 by R. Sterneck-Doudlebský and were conducted with the pendulum of his original construction. In the mine area of Příbram, the seismological experiments made by H. Bendorf took place in 1903/5. In 1908, the seismological station, led by G. Irgang, began to operate permanently in Cheb in order to provide instrumental records of earthquake swarms occurring in the region of Vogtland.

After the declaration of the Czechoslovak Republic, the State Institute of Geophysics was established in 1920. The first director was Václav Láska, and the main research activities consisted of regular measurements and interpretation of gravitational, seismic, geomagnetic, geoelectric, geothermal and radioactive geophysical fields. Systematic geophysical mapping of the state territory was carried out. In 1924, a 1000-kg Wiechert horizontal seismograph was installed in Prague. During the Second World War, the State Institute of Geophysics was dissolved, and all geophysical activities were stopped. After 1945, the Institute was re-established and oriented towards the basic geophysical research. In 1952, the Institute of Geophysics was included among the establishment of the new highest scientific institution of the Czechoslovak Academy of Sciences. New permanent geophysical observatories were established during the 60’s and 70’s, e.g. a geomagnetic, seismological and telluric observatory in Průhonice, an electromagnetic and telluric observatory in Budkov and a tidal station in the mines of Příbram. In 1973, very broadband recording equipment, developed by A. Plešinger, was put into operation at the seismic station Kašperské Hory. It was the first broadband seismic station operating in the world.

Czech Geophysical Milestones

1771 – beginning of the surface air temperature measurements in Clementinum
1804 – beginning of the precipitation measurements in Clementinum
1804 – first geomagnetic observations
1882 – establishment of the Czech Academy of Sciences and Art
1882 – first gravity measurements using pendulum in Příbram
1908 – seismic station Cheb (Belar-Zlatorog seismograph)
1920 – establishment of the State Institute of Geophysics in Prague
1924 – seismic station Prague (Wiechert seismograph)
1945 – re-establishment of the State Institute of Geophysics
1952 – foundation of the Czechoslovak Academy of Sciences, including the Geophysical Institute
1952 permanent geomagnetic measurements in Průhonice
1973 – first routine very broad-band seismic measurements in the world at Kašperské Hory
1989 – beginning of the transformation processes in the Czechoslovak Academy of Sciences
1993 – establishment of the Academy of Sciences of the Czech Republic



The Geophysical Institute represents today a fairly compact body subdivided into five scientific departments covering major geophysical disciplines: seismology, gravity, heat flow/radiometry, geomagnetism and geoelectricity. The activities of the Geophysical Institute include, above all, observatory and field measurements for the purpose of continuous monitoring of various geophysical fields on the territory of the Czech Republic in connection with adjacent parts of central Europe, co-operation with world-wide data network services and data centres, geophysical studies of the lithosphere structure, laboratory investigations of petrophysical properties of rocks, crustal studies, theoretical and numerical modelling of geophysical fields, interpretation of geophysical data, climatic changes in connection with solar activity and solar motion.

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Departments of the Geophysical Institute

Department of Seismology

Seismic networks

Seismological observations on the territory of the Czech Republic have a tradition of more than 80 years. The first seismic station was established in Cheb in 1908. Since that time, seismic observations have been carried out permanently. The seismic data serve as input information for experts and their reports, reviews, and regularly produced bulletins required by the national economy (power plants, building industry, mines, dams, radio telecommunications, and health services). The Department of Seismology is responsible for the operation of the National Seismic Network covering the territory of the Czech Republic, and of the Local Seismic Network in Western Bohemia (WEBNET). The Department publishes seismological bulletins and collects and evaluates macroseismic reports on earthquakes felt on the territory of the Czech Republic.

The department operates four permanent seismological stations of the National Seismic Network (Fig. 1): Průhonice (PRU, since 1957), Kašperské Hory (KHC, since 1961), Dobruška/Polom (DPC, since 1992) and Nový Kostel (NKC, since 1989). Stations PRU, KHC, DPC and OKC are involved in global seismological data exchange and provide data on a regular basis to international seismological centres in the U.S.A., Great Britain, Russia, France and Germany. Station KHC is known as the first routine very broadband station in the world (the broadband system installed by A. Plešinger, and operated since 1973). Station DPC is one of the European broadband telemetric stations included in the global Nearly Real Time Data System SPYDER run by Consortium I.R.I.S. (Incorporated Research Institutions in Seismology). In co-operation with the Polish Academy of Sciences, the Institute has been operating VBB research seismic station Ksiaz (KSP) for 16 years.

The Local Seismic Network WEBNET has been operated by Geophysical Institute in co-operation with the Institute of Rock Structure and Mechanics of the Academy of Sciences of the Czech Republic since 1993. WEBNET consists of eight digital seismic stations. Four of them, Nový Kostel (NKC), Kraslice (KRC), Kopaniny (KOC) and Lazy (LAC) are located in individual epicentral areas in West Bohemia, recording reliably even very weak micro-earthquakes (events with magnitudes $M_L \geq -0.5$). The remaining four stations, Skalná (SKC), Studenec (STC), Horní Částkov (CAC), and Trojmezí (TRC) are located outside the epicentral areas to ensure the best possible areal and azimuthal coverage of the studied region.

Laboratory of seismic observations and interpretations

The laboratory provides the following services:

- Daily analysis of digital and analogue seismograms, locations and magnitudes of local and regional seismic events.
- Global data exchange of both seismogram readings and digital records is carried out with international seismological centres (International Seismological Centre, ORFEUS Data Center, IRIS DMC) and with neighbouring observatories.
- Archiving of digital records on CD-ROMs. Broadband records of selected earthquakes are provided to the European-Mediterranean Data Center ORFEUS and the IRIS Data Management Center.
- Publishing of seismological bulletins and collection and evaluation of macroseismic reports on earthquakes felt on the territory of the Czech Republic. Results of the localisation, analysis of regional events and seismological bulletins are accessible on Internet for other geophysical institutions, universities, and the public.
- A systematic transcription of unique Czech/Polish very broadband archive (supported by IRIS). The archive consists of several thousands of earthquakes and nuclear explosions recorded by stations Kašperské Hory (1973-1986) and Ksiaz (1976-1996). Frequency-modulated data from the tapes are converted into digital binary form and archived locally on CD-ROMs. The data in the SEED format are forwarded to IRIS DMC in Seattle for incorporation into the global digital database.

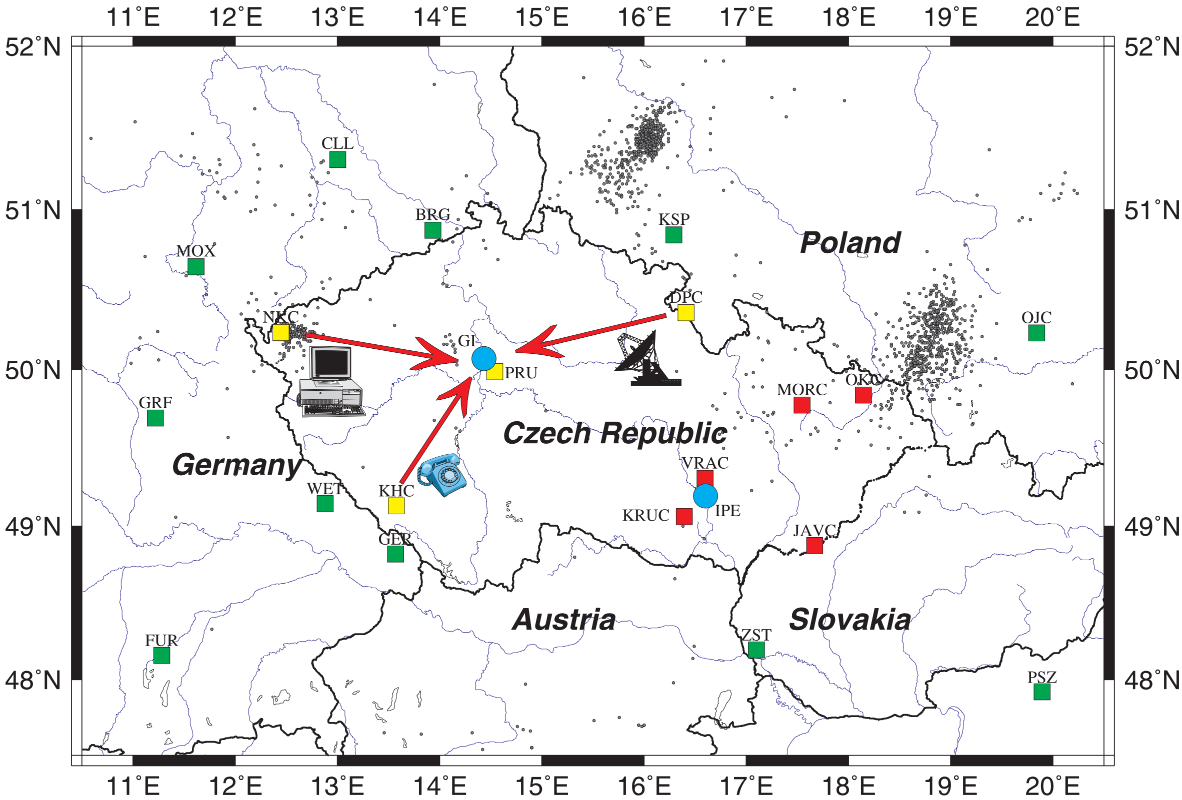

Fig. 1: Czech National Seismological Network. Yellow squares – stations of the Geophysical Institute, red squares – other Czech stations, green squares – foreign stations, blue circles – data centers, and black dots – background seismicity.

Laboratory of theoretical and experimental seismology

The laboratory performs theoretical research into the generation and propagation of seismic waves in complex structures and experimental research into anisotropic structures of the Earth's crust and mantle by the analysis of seismograms.

The research into the propagation of seismic waves includes a development of algorithms and programs for computing seismic wavefields propagating in laterally varying, possibly absorbing, layered anisotropic structures using ray method, study of wave propagation in weakly anisotropic media using the first-order perturbation theory, calculation of reflection/transmission coefficients for weak-contrast interfaces separating weakly anisotropic media and analytic calculations of higher-order ray approximations of seismic wavefields.

The theoretical modelling of the seismic source and its rupture history comprises development of algorithms for source parameter inversion, in particular, a development of the so-called two-step algorithm (first, deconvolution of independent moment tensor rate functions, second, their reduction to constant mechanism and to source time function) by incorporating genetic algorithms. The application of the algorithms for seismic source inversion covers acoustic tremors (co-operation with Keele University, U.K.), volcanic tremors (co-operation with Trieste University, Italy) and tectonic earthquakes (co-operation with NIEP Bucharest, Romania).

Anisotropic structure of the Earth's crust and upper mantle is studied using both body and surface waves, including study of P wave residua and polarisation of the SKS waves. The research is focused on the contact zone of Saxothuringicum and Moldanubicum in Central Europe, a prominent structure between two Variscan units (in co-operation with IPGP Paris, France).

Laboratory of tectonics and geodynamics

Research activities of the laboratory are based mainly on the analysis of the distribution of earthquake hypocentres and on the earthquake source studies. This approach facilitate the delimitation of individual tectonic structures, the determination of the character of their mutual displacement and the state of stress in them, and the correlation of seismicity with other manifestations of geodynamic activity as volcanism/magmatism, geochemical parameters of groundwater, recent crustal movements etc. Geographically, the activities of the Laboratory cover the western part of the Bohemian Massif (West Bohemia/Vogtland earthquake swarm region) and two active convergent plate margins – the Indonesian island arc and Andean South America.

In the West Bohemia/Vogtland earthquake swarm region, seismic activity is monitored by the WEBNET network. After procedures of seismogram processing, location of events and source mechanism determination, the uncommon pattern of seismic energy release has been analysed and correlated with some other geophysical parameters (see paragraphs on gravimetric research). The research is performed in co-operation with the Institute of the Physics of the Earth, Masaryk University in Brno, and with German geophysical institutions (e.g. GeoForschungsZentrum Potsdam, University of Munich, and Seismological Central Observatory Erlangen).

The analysis of seismicity at convergent plate margins is based on catalogues of the International Seismological Centre (ISC) and recently on relocated ISC and NEIC earthquake data for the period 1964-1995. Fault plane solutions from the list of Harvard centroid moment tensor solutions have been used. The research integrates seismological analysis with accumulated geological knowledge in co-operation with partner institutions (Southeast Asia Research Group of the University of London, UK; University of Göttingen, Germany).

Laboratory of Global Tectonics and Metallogeny, European Centre Prague, the common project of the Academy of Sciences of the Czech Republic and the American University, Washington D.C., is included in the framework of the laboratory.

Laboratory of seismic modelling

The laboratory consists of two parts – high-pressure laboratory and laboratory of acoustic emission.

In the high-pressure laboratory, various kinds of specimens (amphibolites from the Bohemian Massif, amphibolites from the world’s deepest borehole on the Kola Peninsula, olivinic basalts from the Ivrea zone) have been used in determining the dependence of P wave velocity anisotropy on depth and pressure, comparison being made with the geological structure and ultrasonic logging. In processing the results of rock anisotropy, a method of omnidirectional analysis is used. By this method the non-linear effect of microcracks in the rock can be separated from the pressure properties of the rock’s mineral skeleton due to which linear dependence is being assumed.

In the laboratory of acoustic emission, relations between acoustic emission and electromagnetic phenomena are studied. In the course of the research, a number of unique and special preparations and equipment have been designed and constructed. This includes a light-tight shielding chamber which was specially designed for the loading equipment used. Apart from the specimen being loaded, this chamber can also house a number of sensors and electronic devices, inclusive of their power supplies, which has made it possible to minimise external electromagnetic interference during measurements.

Department of Geomagnetism

The Department of Geomagnetism deals with traditional and modern geomagnetic research.

The traditional research includes

- recording of the geomagnetic field at the observatory (more then 150 years),
- geomagnetic field network mapping (the first one 135 years ago).

Under modern research we understand

- theoretical modelling of geomagnetic field generation,
- environmental magnetism and rock magnetism,
- study of geomagnetic activity in connection with weather and climate,
- laboratory experiments with very weak magnetic fields.

Traditional research

Observatory measurements. Observatory measurements provide information about short-period variations of the geomagnetic field, but also provide a possibility of calculating secular variation, westward drift, and local geomagnetic anomalies from the field measurements. The Department operated the geomagnetic observatory at Průhonice (1951-1966) in the past; since 1967 it has operated the observatory at Budkov. Budkov is the national geomagnetic observatory present in the list of World Geomagnetic Observatories providing digitised data since 1988 and direct digital data since 1993. The observatory is a member of the INTERMAGNET network and the data are published on the INTERMAGNET CD-ROM.

The observatory has been recently operating two basic systems: a set of BOBROV analogue variometers (3 components D, H, Z), the data of which are manually digitised, and a triaxial NAROD ring-core 'Fluxgate' magnetometer with an ELSEC proton magnetometer (PPM), which produces digital data directly.

K-indices, hourly mean values are published regularly in the Bulletin and submitted to WDC Boulder and 22 co-operating European observatories. Digital data are sent daily to GIN in Edinburgh. Modern algorithm calculating K-indices is used (Sucksdorff's algorithm) and real-time data from the observatory enables geomagnetic activity to be forecast.

Network mapping. After geomagnetic mapping campaigns carried out on the territory of the Czech Republic in 1858, 1894, 1950 and 1978, the fifth geomagnetic mapping was completed in 1996 at 199 geomagnetic sites. The measurements were made first time with D&I Flux magnetometer Bartington MAG-01 mounted on a ZEISS 010B theodolite and with a Proton magnetometer GEM GSM-19G Overhauser. The calculation, filtering and comparison with observatory measurements have been completed and the results were published during 1999 together with maps of geomagnetic elements. The measurements correspond with International Geomagnetic Reference Field (IGRF) over the territory of the Czech Republic.

Measurements at 6 secular points every 2 years enable updating of maps of magnetic elements every year during more than 10 years. In the period when the actual measurements at the secular points are not available, a modern method of forecasting the secular variation for 2 - 4 years is used. The estimation of the 11-year period of the secular variation plays a crucial role in the prediction; prediction maps can be constructed which usually agree with later measurements at secular points up to ±5 nT.

Modern research

Geomagnetic field generation. The generation of the geomagnetic field is studied in accordance with the so-called DYNAMO THEORY. This theory comprises sophisticated numerical modelling performed by the research group of the Department. This group attempts to solve fully three-dimensional models considering small viscosity.

Environmental magnetism and rock magnetism. The environment in many areas of the Czech Republic is exposed to industrial activity, and thus quantification of environmental pollution is required. For this purpose, pollution magnetometry has been applied. Compared to chemical analyses,

Fig. 2: Orthogonal Helmholtz coils

magnetic methods are much faster, less expensive and enable acquisition of large data sets. Pollution magnetometry is applied to mapping the distribution of power-plant fly ashes in soils, contamination of fluvisols and stream sediments. The research is performed in co-operation with researchers from Poland, Germany and France.

Geomagnetic activity, weather and climate. ‘Sun-weather’ research is a traditional branch studied in the Department. Correlation maps indicate that geomagnetic activity affects temperature and pressure fields at least as far as solar activity is concerned particularly in the Northern Hemisphere during the winter. The Department also provides forecasts of geomagnetic activity. The forecast is based on real-time data from Budkov observatory and on daily observations of the Sun carried out by the Astronomical Institute at the observatory Ondřejov. This information is complemented by solar activity data, coronal hole data and geomagnetic indices from WDC Boulder, which are supplied via INTERNET. YOHKOH satellite soft X-ray images have been used since 1995 to improve the quality of the forecast.

Very weak magnetic fields. A system for measurement of very weak magnetic fields was developed under the co-operation with the RS DYNAMICS company. This system offers the computer control of the temperature with an accuracy of hundredths of centigrade and it is based on a system of orthogonal Helmholtz multicoils (Fig. 2). This arrangement enables the measurement of relatively large samples (up to 50×50×50 cm) in a magnetic vacuum within the environment of precisely stabilised and controlled temperature. The system was created to serve for research in environmental magnetism and rock magnetism; however, it is also used for a medical research. More details concerning this research are available at the web site http://www.rsdynamics.com.

Department of Geothermics

The Department of Geothermics focuses on research into the temperature field of the Earth's crust and upper mantle. The temperature distribution has been studied both experimentally by temperature logging in boreholes and theoretically by extrapolation of the borehole temperature data to a greater depth. The extrapolation is based on solving the heat transfer equation in the geothermal model of the studied part of the Earth's interior. In order to compile the model, information about distribution of heat sources, thermal conductivity and diffusivity is necessary together with knowledge of boundary conditions (temperature and its gradient) and the initial temperature field. The instrumental equipment necessary for carrying out this research consists of a portable thermometer for borehole logging to a depth of 1 km, rock thermal conductivity and diffusivity meters and the gamma-ray spectrometer for determination of the radiogenic heat production of the rocks.

The main effort has been concentrated on the regional geothermal studies, which resulted in an updated map of the terrestrial heat flow of the former Czechoslovakia. The map provides information on the geothermal activity of individual geological units of the Bohemian Massif and its surroundings, which have been used to assess deep crustal and lithospheric temperatures.

The most recent activities of the Department have covered a few topics, which are shortly described below.

The temperature field of the Bohemian Massif. Special attention has been paid to the redistribution of heat flow contribution from deeper parts of the crust by the forced convection of groundwater in permeable layers of the Bohemian Cretaceous Basin sediments. The subsurface temperature was measured in the northern part of the basin in a group of 8 boreholes drilled in a hydrogeologically active area with a pronounced relief (400 m within 2 km from the borehole sites). The subsurface temperatures have been also studied on a set of 46 borehole logs measured in the vicinity of uranium deposits in the Bohemian Cretaceous Basin. An interpretation of borehole temperature profiles in terms, e.g. of the groundwater movement or the subsurface climate change signal, requires also better understanding of the effect of topography on the subsurface temperature field. A relationship between the mean annual ground surface temperature (GST) and the attitude of the surface was studied on the data set from 7 temperature-depth profiles measured in boreholes located in a forest in the Krušné Hory Mountains. The extrapolated GSTs were related to the elevation and the slope attitude (angle and orientation) of the surface.

Thermal history of the sedimentary basins. The first results of paleogeothermal studies in the Lower Palaeozoic Barrandian Basin have suggested that the Lower Palaeozoic sediments experienced complex temperature history with at least two sudden thermal pulses. They could have been related to Silurian synsedimentary volcanism or to the emplacement of the Variscan Central Bohemian Pluton. The effect of the pluton formation on the adjacent rocks was assessed by simulation of the intrusion cooling. It turned out that the distance between the basin and the pluton, 15 km and more, is too large for the direct influence of the sediments by the intrusion heat.

The same methodology was used in assessing the thermal conditions of the contact metamorphism of Silurian black shales by basaltic, 4 m thick sill observed in the Kosov quarry in the Barrandian Basin. The zone of heating by more than 120°C, which was the background temperature experienced by the sediments during their subsequent burial, is limited for the intrusion temperature 800°C to a few metres around the sill.

Climate and borehole. The measured temperature-depth profiles were inverted and used to reconstruct the past climate changes expressed as the ground surface temperature history. Altogether 98 boreholes were analysed and climatic episodes over the past two millennia were identified, including warmer period around 400 A.D, colder times between 700–1000 A.D., the Little Climatic Optimum with its culmination around 1250±50 A.D., and the Little Ice Age with temperature minimum at 1650±30 A.D. Special attention was paid to the most recent warming in the last 35 years (1960–1995). This warming has been particularly intense around Prague and in its vicinity and decreased to the south and southwest. Another area of significant recent warming rate corresponds to the industrial regions of Sudety and Ostrava coal basins. The lowest warming rates were found in southwestern and southern parts of the Bohemian Massif, areas generally forested. Urban growth and industrialisation, similarly as deforestation and consequent land development and/or change in vegetation cover, may contribute to warming and produce smaller or larger regional anomalies.

The formerly drilled experimental borehole located on the institute campus for monitoring ground temperature field changes and soil/air temperature coupling was completed with a new similar experimental hole in southern Bohemia (Kocelovice-hole). A complex set of a number of air/soil thermometers was installed and completed with monitoring of precipitation, snow cover, clouds and wind velocity.

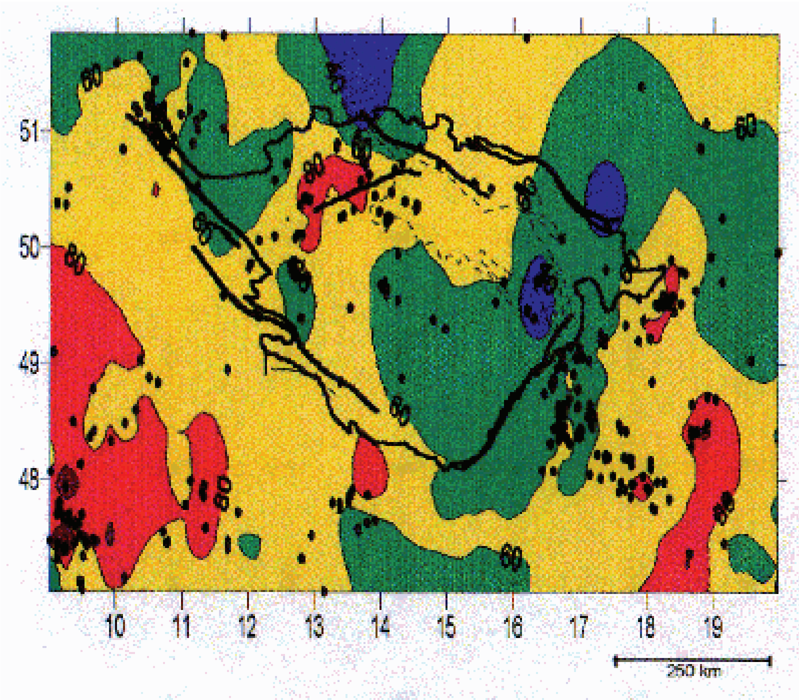

Fig. 3: Heat flow map of the Bohemian Massif, isolines are labelled in mWm^{-2}.

Department of Geoelectricity

The Department of Geoelectricity traditionally concentrates on two basic research topics:

- geoelectrical studies of the solid Earth,
- external geoelectromagnetic fields and solar-terrestrial phenomena.

Regional studies of the electrical manifestation of large-scale tectonic features of the Bohemian Massif and surrounding geological units are one of the primary research interests of the Department. A large amount of regional geoelectrical data has been collected during many years of systematic experiments across the whole territory of the Czech Republic and Slovakia, particularly in areas of large-scale tectonic contacts and transition zones (Fig. 4). A high electrical conductivity is known to be a sensitive indicator of anomalous thermodynamical conditions, fractured zones, fluid saturation, or accumulations of interconnected electronic conductors within the Earth, and thus the regional geoelectrical interpretations have substantially assisted in developing present ideas on the geophysical conditions in the deeper parts of the Earth's crust and in the upper mantle across the principal geological units of Central Europe.

Geoelectrical research in the Bohemian Massif. Recently, concentrated geoscientific research in the western part of the Bohemian Massif, motivated mainly by the KTB deep borehole project in Germany, has largely influenced the regional targets of the geoelectrical investigations. Geoelectrical data indicate a close similarity of the principal geoelectrical features across the whole Oberpfalz block, delineated by the Franconian Line in the west and the West Bohemian fault zone in the east. A three-level model of the electrical structure applies to the upper crust in this area, consisting of an E-W striking crustal conductor at the depth of about 10 km, overlaid by a highly anisotropic crustal layer, with preferred conductivity in the NNW-SSE direction, and a near-surface distorting layer. Recent co-operative German-Czech broadband magnetotelluric measurements along a specially designed SW-NE profile from the KTB area to the Mariánské Lázně ultrabasite complex have proved that the above structural pattern represents a stable and continuous feature across the entire Oberpfalz block. At present, the relation of the principal geoelectrical characteristics of the western part of the Bohemian Massif to the regional tectonic setting is being investigated.

Geoelectrical studies in the West Bohemia/Vogtland seismoactive region. Deep geoelectrical studies assist in detecting and delineating tectonically and seismically significant structural features within the crust. A series of sixteen audiomagnetotelluric measurements was carried out in the region. Despite the excessive industrial completed noise all across the target area, first model interpretation attempts have been completed. The data show the presence of rather extensive conductive structures at relatively shallow depths, within the range of 0.5 km to about 3 km, probably connected with the burried granitic massif beneath the area.

Detection of the first-order tectonic boundaries. Large-scale induction studies often provide reliable, physically substantiated information on the first-order tectonic boundaries within regional geological complexes. Recently, a large collection of previously acquired geomagnetic induction data from the eastern margin of the Bohemian Massif and its transition to the Western Carpathians has been revisited. Originally qualitative, morphological analysis of a set of more than 150 long-period induction arrows across the target area has been extended by the numerical simulation of causative currents for those induction data. The simulations clearly showed that different physical mechanisms are at play for the two prominent induction anomalies observed at the eastern termination of the Bohemian Massif. While the well-known Carpathian conductivity anomaly originates from a clearly defined structure of increased conductivity along the Carpathian Mts. arc, the induction anomaly at the western margin of the Brunovistullicum unit is essentially of a distortion nature, with generating induction processes taking part in conductive structures possibly remote with respect to the area of the anomaly manifestation. A step towards understanding of the system and interactions of the conductivity anomalies on the continental scale has been taken by merging the above regional data set with a large collection of the geomagnetic transfer functions available across the whole of Europe.

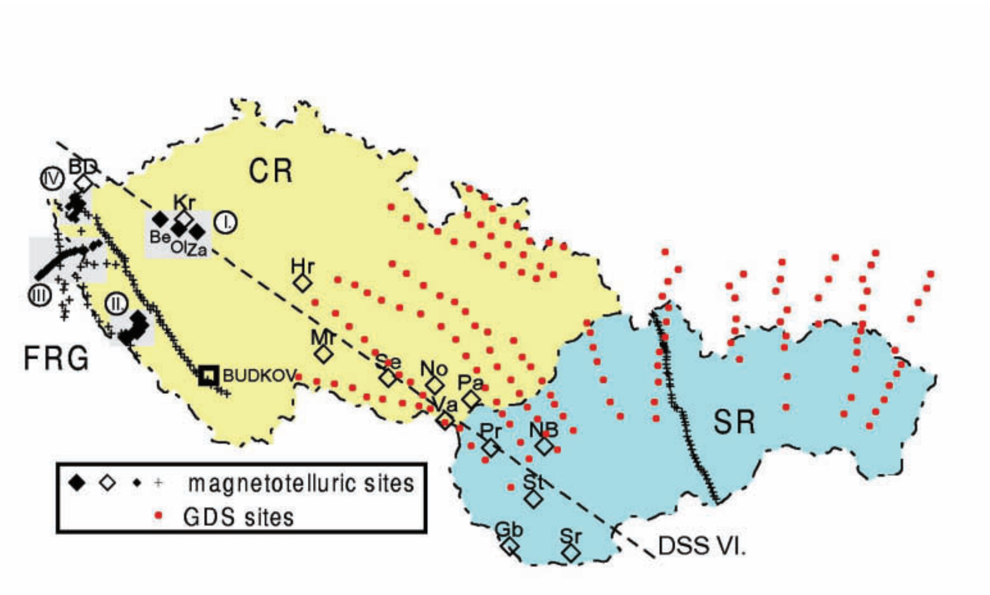

Fig. 4. Long-period MT and GDS measurements with relation to the Bohemian Massif and West Carpathians.

Solar-terrestrial relations. Studies of solar-terrestrial relations represent one of the research directions that has been developing for many years with breathtaking dynamics, mainly due to their presumable immediate and/or long-term impact on man's living conditions in a very general sense. In this direction, one of the most outstanding research topics has developed in the department in the last years, based on the idea that subtle patterns in the dynamical behaviour of the solar system, determined by a joint effect of the Sun and its planets, may play a primary role within the causal chain of solar-terrestrial relations, and in the long-term climatic variations on its terrestrial output, as well. The developed theory aims to provide a prediction tool based on a fully deterministic input signal derived from the dynamics of the solar system. Statistical processing of solar, geomagnetic, volcanic and climatic data has already given a solid support to the underlying theory.

Theoretical research into the electromagnetic wave propagation. A method for numerical modelling of electromagnetic fields in heterogeneous, generally anisotropic media was developed and applied to the interpretation of magnetotelluric data from the western margin of the Bohemian Massif. Recently, anisotropy studies have been extended to other geoelectrical methods, specifically to direct current soundings. A systematic study of various versions of a magnetotelluric inverse algorithm based on the global minimisation controlled random search procedure has been initiated as part of the inverse technique comparison.

Theoretical research into the electromagnetic wave propagation in the Earth's magnetosphere and ionosphere can considerably assist in understanding the physical mechanisms of extra-terrestrial processes. In this respect, significant progress has been achieved recently in elucidating the generation mechanism of the IPDP pulsation. The Earth's ionosphere was studied as an Alfvén resonator, which is able to generate Pc1-type of pulsation on its fundamental frequency at subauroral latitudes. During non-stationary substorm conditions in the ionospheric plasma, the Pc1 can smoothly convert into the IPDP-type of pulsation, with periods decreasing with time. The theoretical conclusions could be proved by a numerical full-wave simulation of the process with the Scandinavian EISCAT data.

Periodicity of the geomagnetic activity. Within the external studies, a statistical analysis with long continuous records of geomagnetic, solar activity and radon activity data has been performed. A detailed investigation of the periodicity of the geomagnetic activity (Ap-indices) within the period range of 5 - 60 days and their correlation with the daily sunspot numbers, based on 1932 - 1991 records, was carried out. The highest peaks were found at periods of about 27 days (solar rotation) and 13.5 days (solar wind speed), with a series of subsidiary peaks distributed symmetrically with respect to the main periods. Less significant peaks were found at periods of about 9 days (origin unknown) and 7 days (connected with the interplanetary magnetic field). No significant response to the synodic month was detected.

Department of Gravimetry

The Department of Gravimetry is mainly concentrated on the following fields:

- gravimetric measurements, data processing, analysis and interpretation,
- investigation of tidal effects,
- geotectonic and sedimentologic studies.

Gravimetric observatories

The department operates the following observatories:

- PŘÍBRAM – observatory for instrumentation tests and data processing. The 'tidal team' consists of electronic engineers and specialised scientists. Except the data from observatories, they also carried out an investigation of the influence of the tides on the radon emissions. The determined correlation can be effectively used for logistics and data evaluation of the radon risk measurements.
- JEZEŘÍ – applied research observatory in the horizontal gallery inside the marginal block of the crystalline complex of the Krušné hory at the edge of an open-pit coal mine. The tiltmeters data are used as an indicator of slope stability and the instrumentation is a part of a complex monitoring system of the mine. The measurement is required by the mine administration. The conditions at this observatory are favourable for the study of the influence of various phenomena on the observed tilts (meteorological conditions – air-pressure and temperature, quarry blasts, natural earthquakes, etc.)
- LAZEC – a research tidal observatory equipped with two tiltmeters, two pure quartz pipe extensometers and one gravimeter. At this site the study of tidal effects should provide representative tidal parameters (amplitude characteristics and phase delays). Such data will serve as a basis for the investigation of crustal deformation by the means of spectral analysis of residual values. In this way the knowledge of deformation in the relatively stable crustal block may contribute to world-wide determination of tidal influence on the Earth crust. When all instrumentation performance is completely stabilised, the data will be included into the world data bank.

Gravimetric research

One of the main tasks is the investigation of temporal variations of gravity in the seismoactive region West Bohemia/Vogtland. Repeated measurements of gravity at selected points have been performed twice a year since 1993 on both sides of the main tectonic feature in the region - the Mariánské Lázně Fault. The data were analysed with respect to the temporal and spatial occurrence of earthquake swarms, mutual position of the foci and indications of the gravity changes, and number of seismic events compared with the amplitudes of the gravity variations. After 4 years of observations, no clear statistical correlation between changes of gravity and the number of seismic events was found, and thus further measurements of a long-term character are necessary in this research. All disturbing effects were studied and their possible influence on gravity evaluated in order to avoid misleading interpretations (blocks displacements, groundwater, ground moisture, temperature and air-pressure, etc.).

This investigation is a part of a complex geodynamic research comprising also the GPS measurements within local and regional networks and precise levelling within a special network at the centre of the most active area near Nový Kostel. While the GPS data do not show any significant horizontal displacements, some of the levelling points exhibit vertical movement up to 10 mm. Such information confirms the existence of movements of crustal blocks. During the study period an interesting change of groundwater level was observed in the well H3 in the Cheb basin before one of the most significant events in December 1994. Another monitoring well was opened in August 1998 in the centre of the focal area.

A special study is being carried out to analyse the stress field as a possible source of gravity variations. Based on sedimentological analysis, the Cheb basin fill characteristics can contribute to the investigation of the tectonic process evolution in the past and its relation to the regional tectonic regime. Detailed knowledge of the tectonic features and sedimentary sequences in the basin are also important for the groundwater motion description. Boreholes located in the Cheb basin were taken as a basis for isopach maps construction for each of the main stratigraphic units: Lower Clays and Sands Formation, Main seam and Cypris Formation, Upper Clays and Sands Formation.

Similar gravity measurements for the investigation of crustal dynamics were started also in different conditions in the Gulf of Corinth, Greece (in co-operation with the National Observatory of Athens), and in the Aswan Lake region, Egypt (in co-operation with the National Research Institute of Astronomy and Geophysics, Helwan). In Greece, the GPS data (IPG Paris) define the block's displacements, but there is no control on stress field regime. For this reason the repeated measurements of gravity were introduced along the southern coast of the Gulf (northern Peloponnesus) with a connection to stations at the northern coast by ferryboat. Significant difference in gravity was determined especially in the eastern part around Nemea and Argo Korintos between 1994 and 1997 campaigns. In 1997 the first campaign of gravity measurements was performed in the Kalabsha region around the north-western bank of the Aswan Lake in Upper Egypt. In this region the seismic activity is affected by the water level in the lake, which depends on annual variations and total amount of water coming from the source regions. Further measurements of gravity, GPS and precise levelling are the basis for complex analysis of the induced crustal dynamics.

Applied research is being performed in microgravimetry with the aim of solving problems of engineering geology, civil engineering, environment and archaeology for both state and private institutions. In order to improve the data accuracy of microgravimetric measurements, new software is under development to introduce a special technique of gravimeter drift determination. In most cases the detection and location of burried voids (natural cavities, caverns or breakdowns around savage systems, historical cellars or tombs, etc.). For example, in the old mining district of Příbram some new voids were indicated along the main road as potential risk phenomenon in the area with existing breakdown on the road. Microgravimetric investigations were also started in Luxor, Egypt, in very complicated conditions of the Valleys of the Kings and Queens, with the aim of discovering buried tombs or galleries. Combined investigations by one-off gravimetric survey (to locate weakened zones), and monitoring of disintegration and dilatation processes by repeated measurements (to determine the change of stability) were carried out on a few landslide localities in order to study slope deformation.

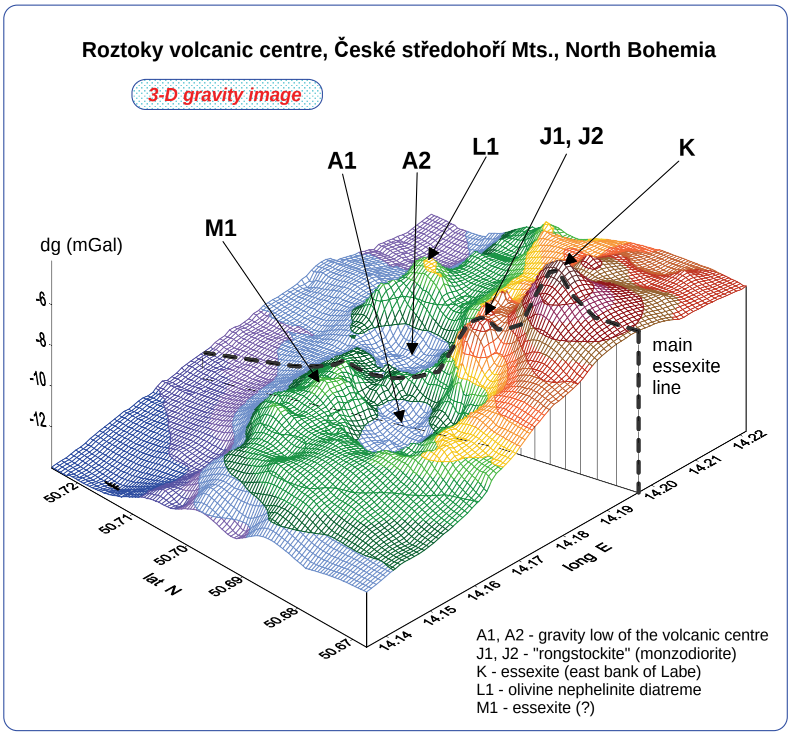

Fig. 5: Application of gravity survey in geological investigations – volcanic area of the České středohoří Mts., North Bohemia.

Research Projects

Seismic Processes and Parameters of the Upper Crust Medium in the West Bohemian Earthquake Swarm Region

(granted by GACR 205/96/0974)

Duration: 1996-1998
Principal investigator: Josef Horálek
Joint investigators: Vladimír Rudajev (Institute of Rock Structure and Mechanics ASCR, Prague), Oldřich Novotný (Faculty of Mathematics and Physics, Charles University, Prague).
Co-workers: Alena Boušková, Jan Šílený, Tomáš Fischer, Petr Jedlička

Recent geodynamics of West Bohemia in relation to the crustal structure (unique natural laboratory)

(granted by GACR 205/99/0907)

Duration: 1999 – 2001
Principal investigator: Josef Horálek
Joint investigator: Vladimír Nehybka - IPE MU Brno
Co-workers: Alena Boušková, Axel Plešinger, Petr Jedlička, Jaroslava Plomerová – GFÚ Prague
Jan Švancara, Zuzana Skácelová - IPE MU Brno

Geodynamics of the West Bohemia Seismic Region

(granted by GAASCR A3012807/1998)

Duration: 1998 – 2002
Principal investigator: Jan Mrlina
Joint investigator: David Jindra (Geoinvest spol. s r.o., Prague)
Co-workers: Aleš Špičák, Josef Horálek, Alena Boušková, Alice Slancová, Lenka Špičáková

Spatial and temporal energy release.

The region of West Bohemian earthquake swarms is monitored continuously by the local network WEBNET consisting of eight digital stations (Fig.6). The first model of spatial and temporal seismic energy release was constructed based on continuous observations from the WEBNET stations. It was found that micro-earthquake activity, mostly of swarm-like character, persisted in the region between the subsequent stronger swarms. The foci of most microearthquakes, recorded after the 1985/86 swarm, cluster in seven focal zones. The seismicity in the main focal zone Nový Kostel, where about 80% of the events recorded since 1986 have occurred, is closely related to the system of principal tectonic faults intersecting the focal region. The foci of the individual swarms recorded in the region tend to cluster into very narrow volumes at depths from 6 to 13 km.

Seismic model of the region.

About 300 travel-times obtained from the temporary stations recording refraction blasts from seismic profiles A/89, B/89, MVE/90 C/91 and D/91 were inverted using the Wiechert-Herglotz method. On the basis of these data a 1-D model of the region for depths down to about 7 km with variable, azimuthally dependent P wave velocities was derived. The model displays the regional crustal anisotropy of 3 % for the P wave velocities. At present, the newly developed isometric inversion method has been applied to the P and S wave onsets data of local microearthquakes to derive a 1-D model for the S wave velocities.

Data from the January 1997 earthquake swarm and their analysis.

The earthquake swarm, which occurred in the period from January 13th to January 27th, 1997, ranks with the largest ones in Western Bohemia since the 1985/86-earthquake swarm in terms of energy release and duration. It has been the best ever-recorded seismic sequence in the region. More than 1600 events were recorded by local stations in the course of it. The largest event reached magnitude $M_L = 3.0$. Altogether 980 events recorded at least at four stations were located and their seismograms were analysed in detail. It was found that the hypocentres formed an extremely concentric cluster at depths of 8.7 km to 9.7 km. All 980 events split into 9 groups based on a similarity of seismograms.

The moment tensors of 70 events (a few for each group) recorded at least at six stations with signal/noise ratio of at least 10 were determined. An inversion of amplitudes of the direct P and S waves for the point source approximation was applied.

The source mechanism study shows that during the swarm activity nine different focal mechanisms occurred (Fig.7). Two of them corresponding to the largest events were predominant. In many cases the moment tensors contained not only a double couple component but also a compensated linear vector dipole and even a volumetric part. Since all the events with known source mechanisms cover the whole period of the swarm activity it was possible to form the first idea about processes acting in the course of the earthquake swarm in the West Bohemia. Based on the focal mechanism data the state of the stress in the region was also analysed in detail.

Seismograms of micro-earthquakes of the January 1997 swarm recorded at the NKC station located immediately above the earthquake foci exhibit complex P and S waveforms which are interpreted as interference of the direct and the reflected P and S waves. These reflections may be interpreted as corresponding to a strongly reflecting boundary at a distance of several hundred meters only from the earthquake hypocentres. Preliminary studies based on comparison of amplitudes of P, PP, S, SS waves obtained from the seismograms and generated by ray synthetics using the ANRAY programme package indicate that a heterogeneity with seismic-wave velocities $V_P = 3$ kms^{-1} and $V_S = 0.1$ kms^{-1}, corresponding to a fluid or partially molten medium, inside the medium with $V_P = 6.5$ kms^{-1} and $V_S = 3.8$ kms^{-1}, could act as such a reflector.

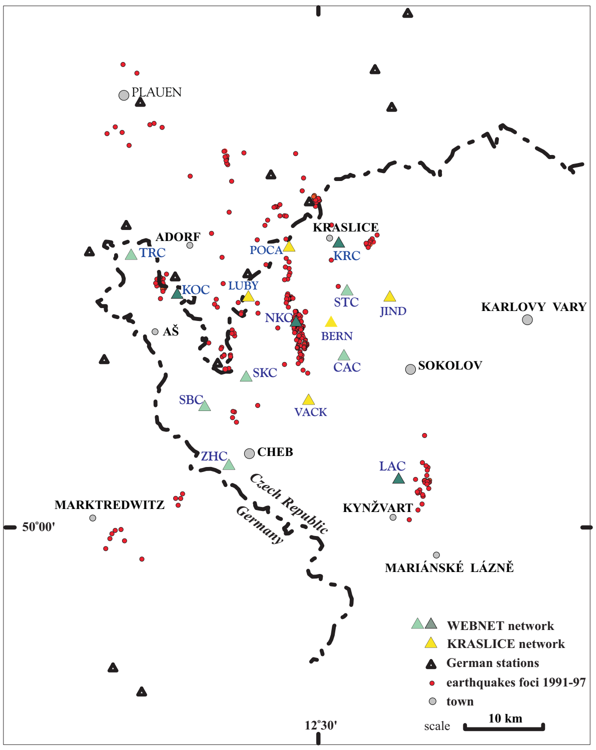

Fig. 6: Map of earthquake's epicentres and stations in the West Bohemian swarm region.

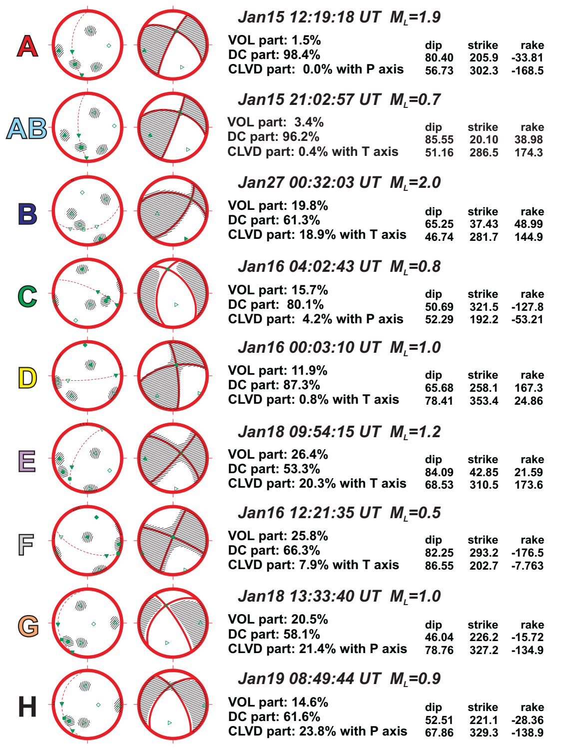

Fig. 7: Nine types of focal mechanisms identified in the January 1997 earthquake swarm.

Geodynamics

Observations of temporal changes of gravity started in 1993 and continued without interruption with two campaigns per annum. A certain increase of the gradient of the gravity changes was observed before the January 1997 swarm in the central area near Nový Kostel. The data are being prepared for complex reprocessing by a new technique of drift correction.

Precise levelling at the focal area of Nový Kostel indicated reverse vertical displacement at the most ‘active’ points. The subsiding tendency 1994 – 1996 was changed for a small uplift in 1997, in 1998 turning back to subsiding. However, the amplitude of displacements (up to 5 mm) is still close to the limit of confidence. The GPS data were recorded in both local and regional networks, but no significant horizontal displacement was recorded.

The monitoring of groundwater level was stopped in one of the two wells as it was often affected by surface water. The system was installed in another well with an extraordinary position in the centre of the active area Nový Kostel. Since the beginning of August 1998 the data have been showing the effect of air pressure and tidal waves.

A tectonic framework based on the digital model of the relief and isopach maps constructed for each of the main stratigraphic units were prepared for the complex analysis of the Cheb sedimentary basin with respect to the tectonic stress regime.

Seismic Anisotropy of the Upper Mantle of Continental Regions - Analysis of Contributions from Different Depths (granted by GAASCR A3012604)

Duration: 1996-1998

Principal Investigator: Jaroslava Plomerová

Co-workers: Vladislav Babuška, Jan Šílený, Daniel Kouba, Jiří Pospíšil, Karel Klíma, Jan Zedník

Co-operating Institutions: I.P.G. Strasbourg, France; LGIT/IRIGM Grenoble, France; University Uppsala, Sweden; SZGRF Erlangen, Germany, IPG Paris, France; MFF UK, Praha;

Seismic anisotropy is becoming an important subject of various studies due to its ability to map directional features of the Earth's structures. Many observations indicate that the dominant effects of anisotropic propagation of seismic waves result from the preferred orientation of olivine, which is the main constituent of the upper mantle. The project aims at studying different contributions to the observed anisotropic effects and their relation to geodynamic processes. These effects originate in orientated structures within the rigid continental lithosphere, as well as within the ductile underlying asthenosphere. The study is based on both the inversions of splitting parameters of the shear waves at different frequency ranges and the anisotropic tomography of the longitudinal waves, with the aim to retrieve 3-D anisotropic models with arbitrary orientated symmetry axes. Lateral changes in anisotropic structure of the subcrustal lithosphere, related to deep sutures, were studied in two regions: around the Saxothuringian and Moldanubian (S/M) contact in the western rim of the Bohemian Massif and across the Protogine zone (PZ) in south central Sweden (Fig. 8). Both divergent and convergent orientations of dipping anisotropic structures with hexagonal symmetry in adjacent lithospheric blocks separated by the sutures were retrieved.

To separate anisotropic effects from various depths we have applied a wavelet transformation. However, most useful information on a depth source of the anisotropy (Fig. 9) was extracted from variations of the radial and azimuthal anisotropy of surface waves. Moreover, these parameters allow us to study independently large-scale fabric of the mantle lithosphere and its relation to the geological age of large tectonic units. Orientation of azimuthal anisotropy within a ductile part of the upper mantle is furthermore incorporated into modelling of mantle convection.

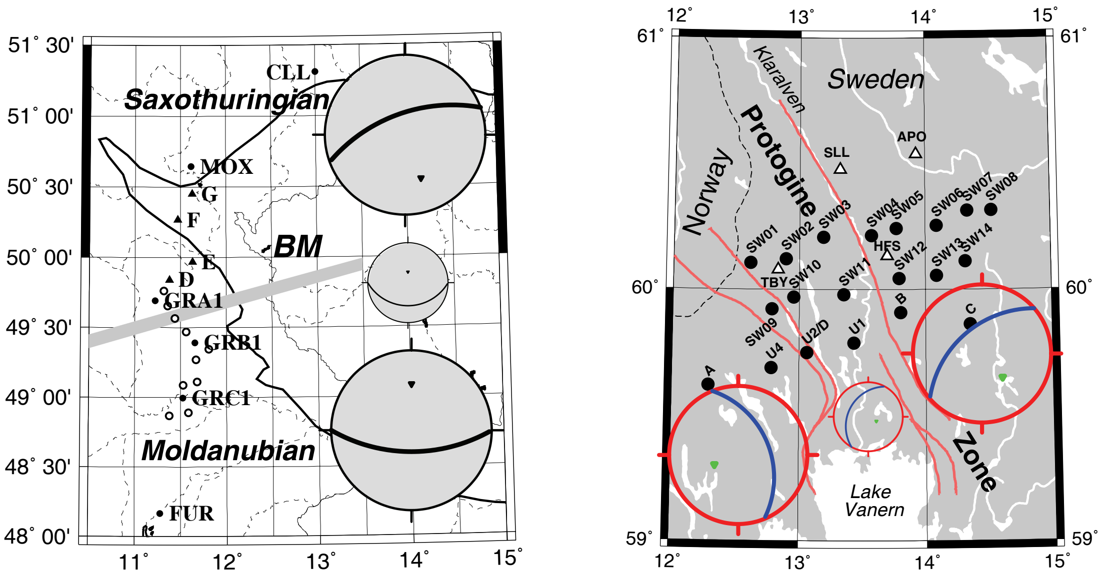

Fig. 8: Self-consistent 3-D anisotropic models of the subcrustal lithosphere as derived from body waves - around the Saxothuringian and Moldanubian (S/M) contact in central Europe with divergent orientation of dipping anisotropy (left) and around the Protogine Zone (PZ) in south-central Sweden with convergent orientation of dipping anisotropy (right). The triangles mark the 'low-velocity' symmetry axes and the curves the dipping high-velocity planes in projections of the lower hemisphere. Dots and black triangles represent seismic stations operating during the French-Czech-Swedish field measurement in 1991 (PZ) and the Czech passive experiment (S/M) in 1992, both supported by grants of the Grant Academy of the Czech Academy of Sciences (Nos. 31225/1991-92; A312115/1993-95).

A special issue of Pure and Applied Geophysics Nos. 2-4, vol. 151 on 'Geodynamics of Lithosphere & Earth's Mantle: Seismic Anisotropy as a Record of the Past and Present Dynamic Processes', edited by J. Plomerová, R.C. Liebermann and V. Babuška, was derived mainly from papers presented in an International Workshop held on July 8-13, 1996 at the Chateau of Třešť in the Czech Republic and convened by the editors.

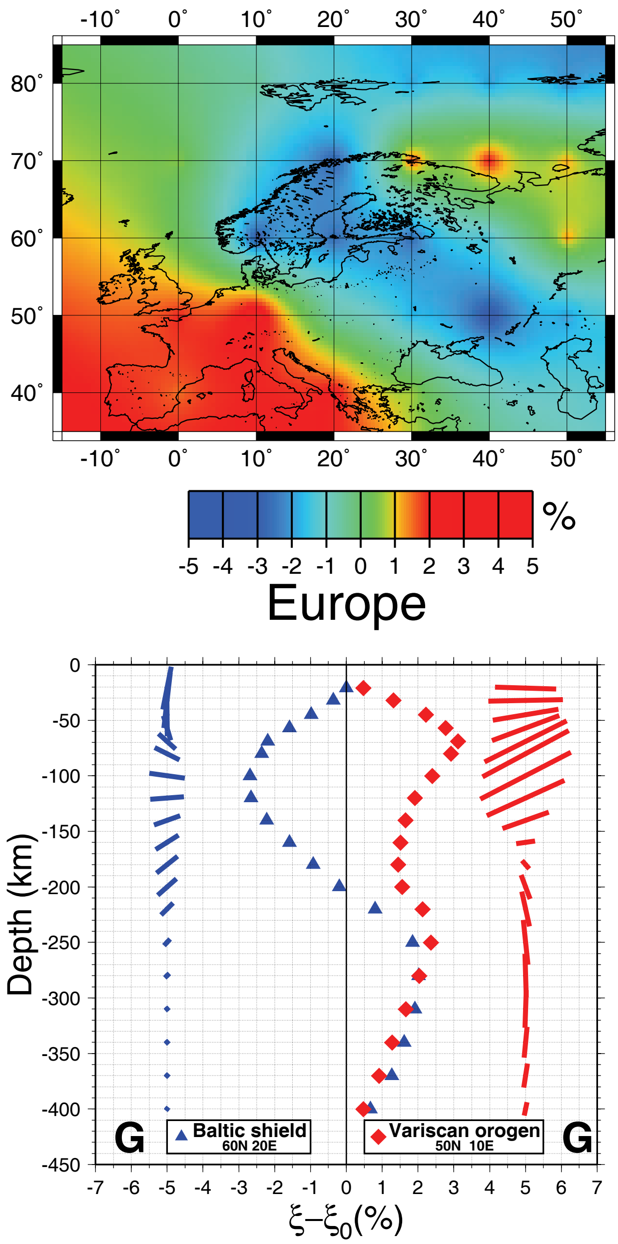

Fig. 9: Lateral variations of the maximum amplitude of the relative radial anisotropy in the subcrustal lithosphere of Europe. The Trans-European Suture Zone is the most prominent geological boundary separating mobile Phanerozoic terranes, characterised by less inclined anisotropies (positive values) from steeply plunging anisotropic structures beneath the Precambrian East-European Platform (negative values).

Orogenic Roots - Processes, Manifestation and Implication for Evolution of Continental Lithosphere (granted by GACR 205/98/K004)

Duration: 1998-2002
Principal Investigator: Karel Schulmann (Faculty of Science, Charles University, Prague)
Joint Investigator: Jaroslava Plomerová
Co-workers: Vladislav Babuška, Jan Šílený, Daniel Kouba
Co-operating Institutions: Faculty of Science, Charles University Prague; University of Strasbourg, France;

The project aims at identification and quantification of processes in thickened continental crust, which developed during continental collision, and at studying their relation to structure and fabric of the upper mantle. The first year of the project was characterised by field studies in the Bohemian Massif (BM) and French Massif Central. Three new mobile broadband digital seismological stations (BM1-3, Fig. 10) have started operation within the project in August 1998, to record teleseismic events. Additional five digital stations (BM4-8) have been deployed in the BM and running for 9 months within a grant of Ministry of Education No. 98087 (project MOSAIC – Barrande) to cover the Bohemian Massif by a dense network of stations allowing us to study in detail its seismic velocities (anisotropy) and structure, and map depth boundaries (e.g. lithosphere-asthenosphere transition) as well as boundaries of geotectonic units. A detailed tomographic research of lithosphere of both Variscan Massifs will be based on body wave data recorded by the mobile network (BM) and on data extracted from databases of permanent seismological observatories in the region and its surroundings.

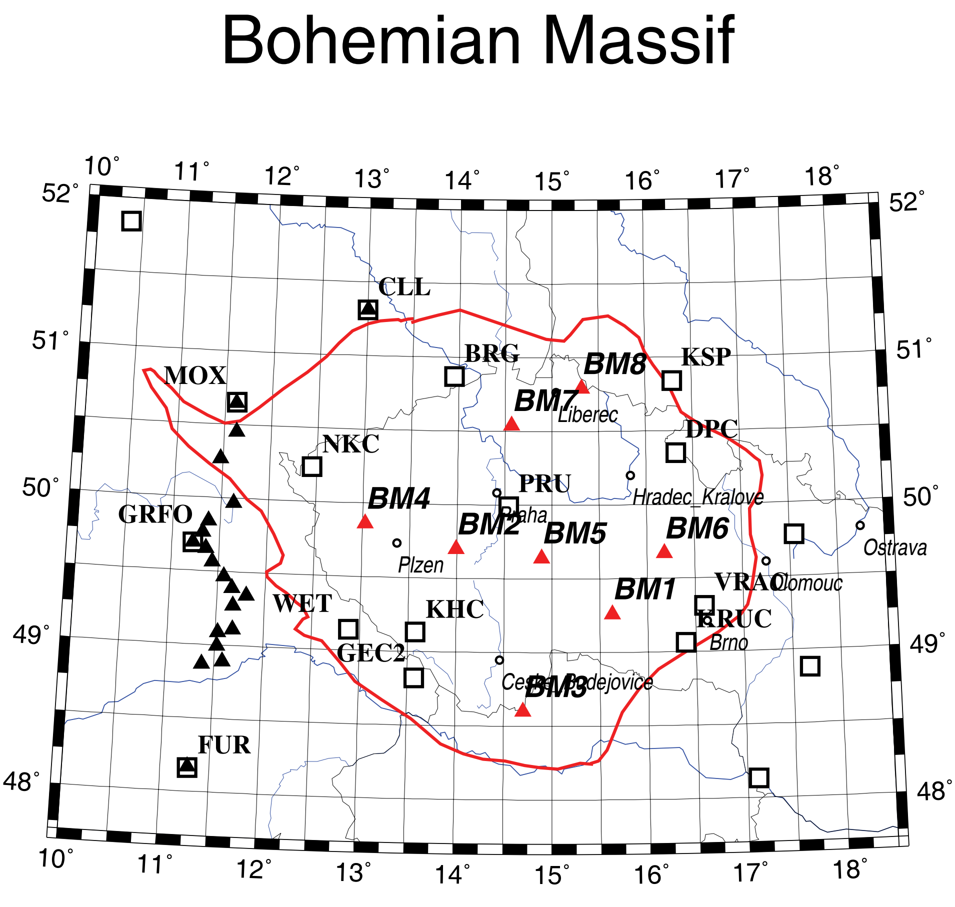

Fig. 10: Mobile seismological stations (BM1 – BM8, red triangles) installed in the Bohemian Massif (BM) to record teleseismic waves for anisotropic tomography of the lithosphere and upper mantle. Permanent broadband seismological observatories in the BM are marked by squares.

Study of Elastic Anisotropy of Rocks under Hydrostatic Pressure up to 400 Mpa

(granted by GAASCR A3012603)

Duration: 1996-1998
Principal investigator: Zdeněk Pros
Co-workers: Karel Klíma, Tomáš Lokajíček, Richard Přikryl

The principal objective of the project was to investigate the elastic properties of rocks geologically belonging to the lower crust and transition zone of the upper mantle by laboratory measurements of the kinematic and dynamic parameters of elastic waves passing through spherical rock samples under varying hydrostatic pressure, to study the nature of microcracks, their closing and their influence on signal filtration. An integral part of the project is the improvement of the already existing measuring system, which now enables the dynamic and spectral parameters of elastic waves propagating in anisotropic media to be studied. Regarding the improvement, not only the hardware, but also the software of the measuring system was changed. This change now enables the whole waveform of the ultrasonic signal (first 40 μs) to be recorded and thus also the anisotropy of the amplitude or the spectral changes of the transmitted signal to be analysed. More than 30 spherical samples from the Ivrea Zone, Bohemian Massif, from both deep KTB boreholes and deep SG3 Kola Peninsula borehole were measured and studied.

Investigation of the Texture of Rocks by Ultrasonic Waves and Neutron Diffraction

(granted by GACR 205/97/0905)

Duration: 1997 - 1999
Principal investigator: Zdeněk Pros
Co-workers: Karel Klíma, Tomáš Lokajíček, Richard Přikryl, Jana Kotková, Ladislav Padjen, A.N. Nikitin, T. Ivankina

The principal task of the project was the investigation of the relationship between the texture of rocks and their physical properties, especially the kinematic and dynamic parameters of acoustic waves. The proposed approach is based on texture determination by neutron diffraction and on the determination of the properties of acoustic waves after passing through the rock sample. Identical samples of spherical shape can be used in both methods.

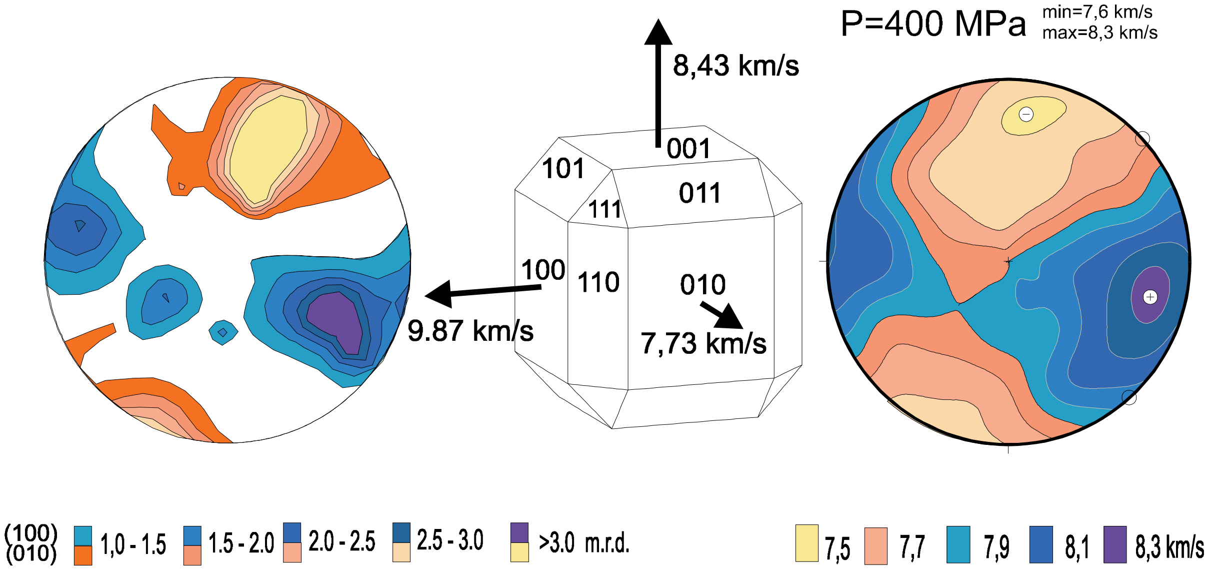

Fig. 11: Olivine sample - comparison of pole figures derived from neutron diffraction for (100) and (010) orientations (the pole figures are combined into one picture) with P wave anisotropy determined for 400 MPa by ultrasonic sounding.

The anisotropy of P wave velocities has been studied on spherical samples in a range of confining pressures from 0.1 to 400 MPa. The spherical shape of the sample enables the spatial distribution of P wave velocities to be investigated for any pressure value, and this can be used to derive the changes of velocity with pressure for any direction. The standard procedure based on neutron diffraction was used to determine the sample structure. Pole figures were determined on the basis of the time-of-flight method. The results of neutron structure analysis allow the elastic anisotropy of solid bodies to be interpreted.

The results show that neutron diffraction provides quantitative texture data and has several advantages over conventional X-ray diffraction. Most important is the high transmission for most materials, the measuring of pole figures on large coarse-grained samples and the measuring of all pole figures with a high accuracy (no corrections) simultaneously. The method is especially useful for geological samples, which are often composites of low symmetry constituents and, therefore, characterised by complex diffraction patterns with numerous partly and completely overlapping Bragg reflections. Theoretically, the textures of all mineral phases may be determined even from such complicated experimental data. The advantage of the neutron diffraction on spherical samples is that the scattering takes place in the whole sample volume. Consequently, the average texture of the whole sample is obtained.

The aim of this project is to study the natural and artificial spherical samples, diameter 50±0.01 mm, and the comparison of their P wave anisotropy expressed in terms of isolines, their texture determined by means of neutron diffraction (Fig.11).

Determination of Seismic Source Parameters in Geologically Complex Media
(granted by INCO-Copernicus IC15 CT96-200)

Duration: 1997-1999
Principal investigator: R.P. Young, Keele University, UK
Co-workers: Ivan Pšenčík, Jan Šílený, Václav Vavryčuk

Source Parameter Retrieval from Local Seismicity
(granted by GAASCR A3012601)

Duration: 1996-1998
Principal investigator: Jan Šílený
Co-workers: Zuzana Jechumtálová, Petr Kolář, Ivan Pšenčík, Václav Vavryčuk, Johana Brokešová (Faculty of Mathematics and Physics, Charles University Prague)

Mechanism and Time History of Seismic Source Buried in Complex Media
(Technical assistance of Italy to EEC countries in the frame of Law#212, Project #7)

Duration: 1997-1999
Principal investigator: Jan Šílený
Co-workers: Zuzana Jechumtálová, Luděk Urban and Jiří Zahradník (Faculty of Mathematics and Physics, Charles University Prague)

Quantitative Seismic Zoning of the Circum-Pannonian Region
(Copernicus CIPA-CT94-0238)

Duration: 1995-1997
Principal investigator: G.F. Panza (University of Trieste, Italy)
Co-workers: Jan Šílený

Seismic Waves in Anisotropic Media
(granted by GACR 205/96/0968)

Duration: 1996-1998
Principal investigator: Václav Vavryčuk
Co-workers: Ivan Pšenčík, Jan Šílený

Earthquake Source Retrieval with Inexact Model of the Structure
(granted by GAASCR A3012904/99)

Duration: 1999-2001
Principal investigator: Jan Šílený
Co-workers: Zuzana Jechumtálová, Ivan Pšenčík, Václav Vavryčuk

In seismic records, both the effects of seismic source and the medium through which seismic waves travel from the source to the station are coupled. Because ignorance about the medium in a seismic zone under study is rather a rule than an exception in practice, parameters of retrieved source are biased due to the inexact knowledge of the Green's function, see Fig. 12. To mitigate the effect, the source time function used to be estimated by the method of empirical Green's function, group processing offers a chance to determine relative moment tensors or a sufficiently robust inverse method should be used. The latter procedure was followed here: the two-step inverse algorithm recently developed at the Geophysical Institute appeared to behave prospectively when faced with inconsistent forward modelling.

The method was upgraded by considering estimates of noise contaminating the records separately at each channel, and by constructing confidence regions of the retrieved source parameters. Then, it was tested for its robustness when using inconsistent responses of the medium, i.e. the Green's function corresponding to a simplified model of the medium. Three sources of inconsistency were investigated: (i) simplified inhomogeneity, (ii) neglected anisotropy, and (iii) neglected free interface.

(i) Vertical 1-D inhomogeneity of the Friuli, NE Italy, zone was simplified by suppressing slow sub-surface velocities for the stations situated in the mountains, and by their enhancing for the stations located in the plain. Both the mechanism and the source time function were reconstructed very well, contrary to a standard gradient method with a direct parameterisation of the source, which failed.
(ii) It was demonstrated that a rather strong anisotropy (about 20% in P and 10% in S waves) may be neglected, and still we obtain a fairly good estimate of the mechanism and the source time function. Especially the orientation of the mechanism appears to be the feature, which is very stable when inverting anisotropic data by using isotropic Green's function.
(iii) Neglecting a free surface near the hypocentre in the modelling of the Green's function appeared to have a minor effect on the source reconstruction provided that the source time function is not extremely short. The inconsistency is projected mainly in the false source components while its orientation remains largely unharmed.

The conclusion drawn from the above experiments seems to have prospects for further seismological practice: if we do not know parameters of the medium in which seismic source is buried exactly, we may process the data using a simplified model and still have a good chance to expect a reasonable estimate of the source.

An exact analytical formula for the complete Green's function for homogeneous unbounded weak transversely isotropic media has been found. The formula was derived by analytical calculations of higher-order ray approximations of the ray series. The formula for the Green's function is complete and correct for the whole frequency range. It describes correctly the wavefield at all distances and at all directions including the shear-wave singularity direction. The Green function consists of *P*, *SV* and *SH* far-field waves and four coupling waves. Three of them couple *P* and *SV* waves, and the fourth wave couples the *SV* and *SH* waves. The *P*-*SV* coupling waves behave similarly to the near-field waves in isotropy. The *SV*-*SH* coupling wave is called 'shear-wave coupling' and it behaves exceptionally. This wave is important, in particular, for directions close to the shear-wave singularity. The shear-wave coupling considerably affects waveforms and polarisation of quasi-shear waves in regions, where *qS* waves are not well separated. Even if the split shear waves are fully separated in time and thus do not mutually interfere, the shear-wave coupling can cause the polarisation of split *qS* waves to be elliptical. It implies that the zeroth-order ray approximation can be applied only to regions, where the separation time of split shear waves is much larger than the width of *S* pulses. For some directions, this condition can be fulfilled at distances of hundreds of wavelengths from the source.

Approximate displacement *PP* plane wave reflection/transmission coefficients for weak-contrast interfaces in general weakly anisotropic media have been derived. The coefficients were obtained by applying the first-order perturbation theory and they are written in a compact and relatively simple form. The coefficients are given as a sum of the coefficient for the weak-contrast interface separating two nearby isotropic media and a term depending linearly on contrasts of the so-called weak anisotropy (WA) parameters, which specify deviation of properties of the medium from isotropy. The accuracy of the approximate formulae is illustrated on several models. Comparison of the exact and approximate coefficients shows that the approximate formulae are sufficiently accurate for a wide range of incidence angles and for all azimuths (see Fig. 13).

Standard ray method for anisotropic media does not work properly when applied to shear wave propagation in inhomogeneous weakly anisotropic media. To overcome this difficulty, the quasi-isotropic (QI) approach is proposed to be used in weakly anisotropic media. Shear wave synthetics for a VSP (vertical seismic profile) configuration shown in the left hand side of Fig. 14 were generated by a vertical force in the model of a vertically inhomogeneous weakly transversely isotropic medium with a horizontal axis of symmetry (HTI) shown in the right hand side of Fig. 14. The synthetics were calculated by the ray method for anisotropic (ANI) media and by the QI approach. The results are compared in Fig. 13 with results of the ray method for a nearby isotropic medium. For shallow receivers, to which the shear waves propagate along short paths with only slightly different phase velocities (see red circled area in Fig. 14), the two shear waves are coupled and the QI section resembles the ISO section; the ANI section shows incorrectly strong transverse displacement generated by a vertical force in a nearly isotropic medium. For deeper receivers, to which the shear waves propagate along longer paths with more different phase velocities (see blue circled area in Fig. 14), the waves decouple and the QI section resembles more the ANI section. Both sections show shear wave splitting for deep receivers: there is a faster shear wave polarised in a vertical plane and slower wave polarised transversely (see the arrows in Fig. 15). The example shows that the QI approach represents a natural link between the ray methods for isotropic and anisotropic media where neither of the ray methods can be used.

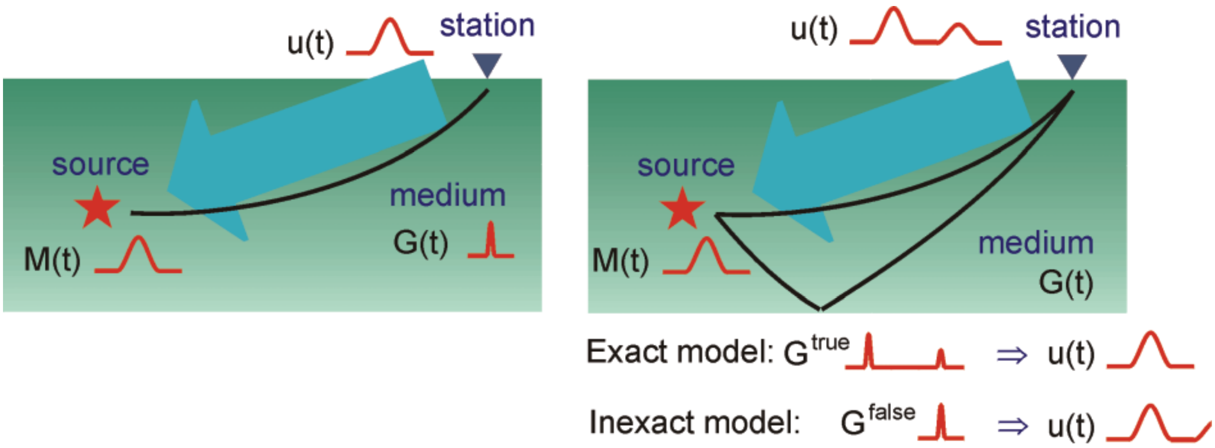

Fig. 12: Inverse modelling of seismic source with inexact estimate of the medium: lost interface.

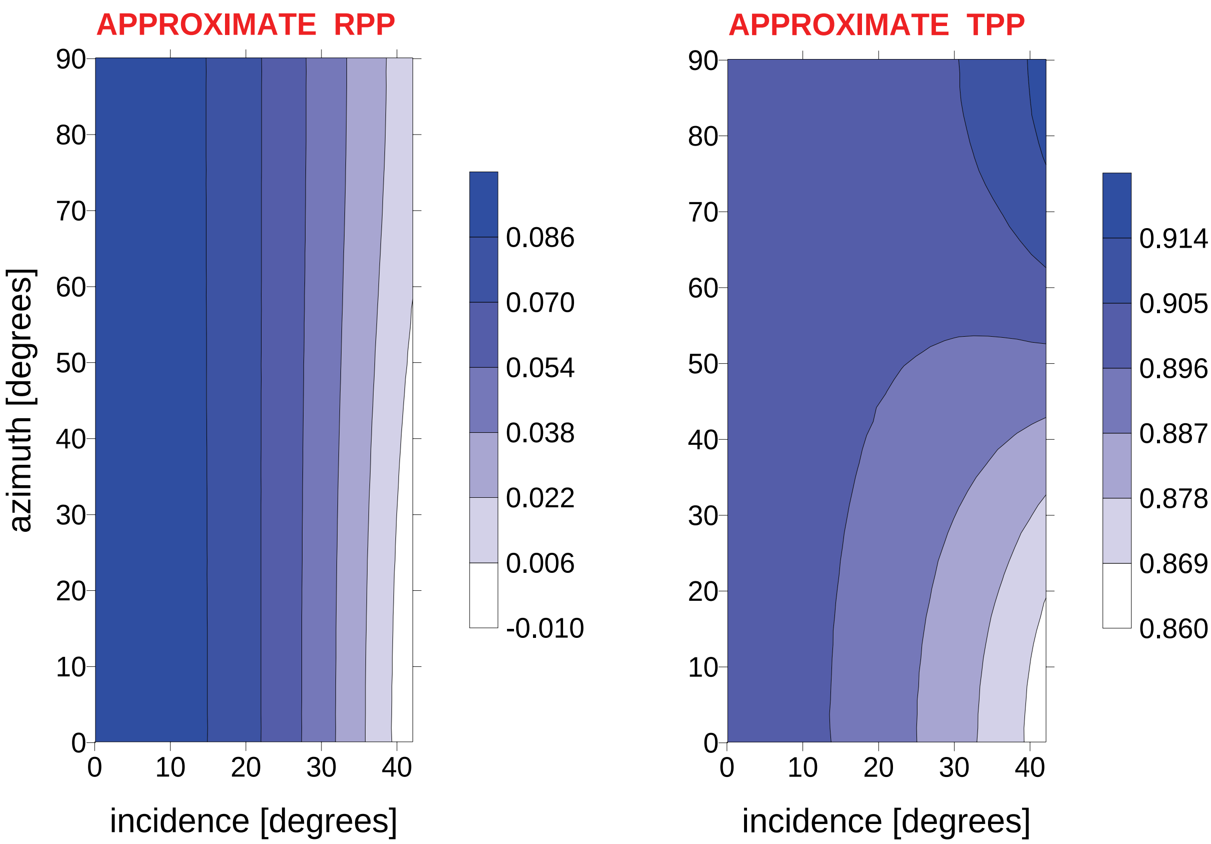

Fig. 13: The maps of the approximate R/T coefficients for an interface separating two weakly anisotropic halfspaces. The upper halfspace: the VTI Mesaverde sandstone, the lower halfspace: the medium with the dry vertical cracks.

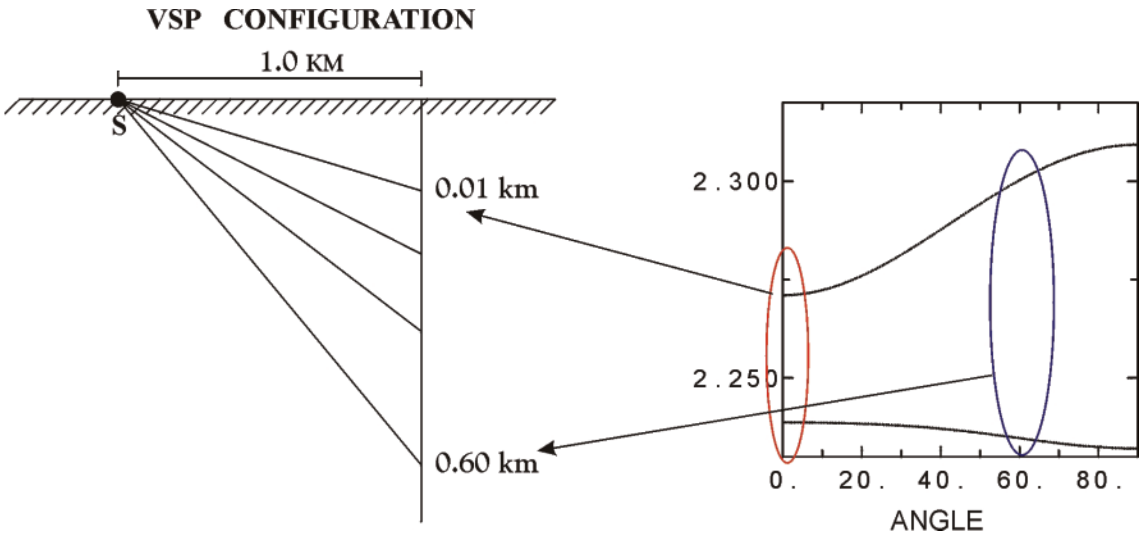

Fig. 14: Left: configuration of the experiment, source - vertical force. Right: section of the phase velocity surfaces of two shear waves by a vertical plane containing the source and the borehole at surface. The angle 0° corresponds to horizontal propagation, 90° to vertical propagation. The phase velocities increase with depth.

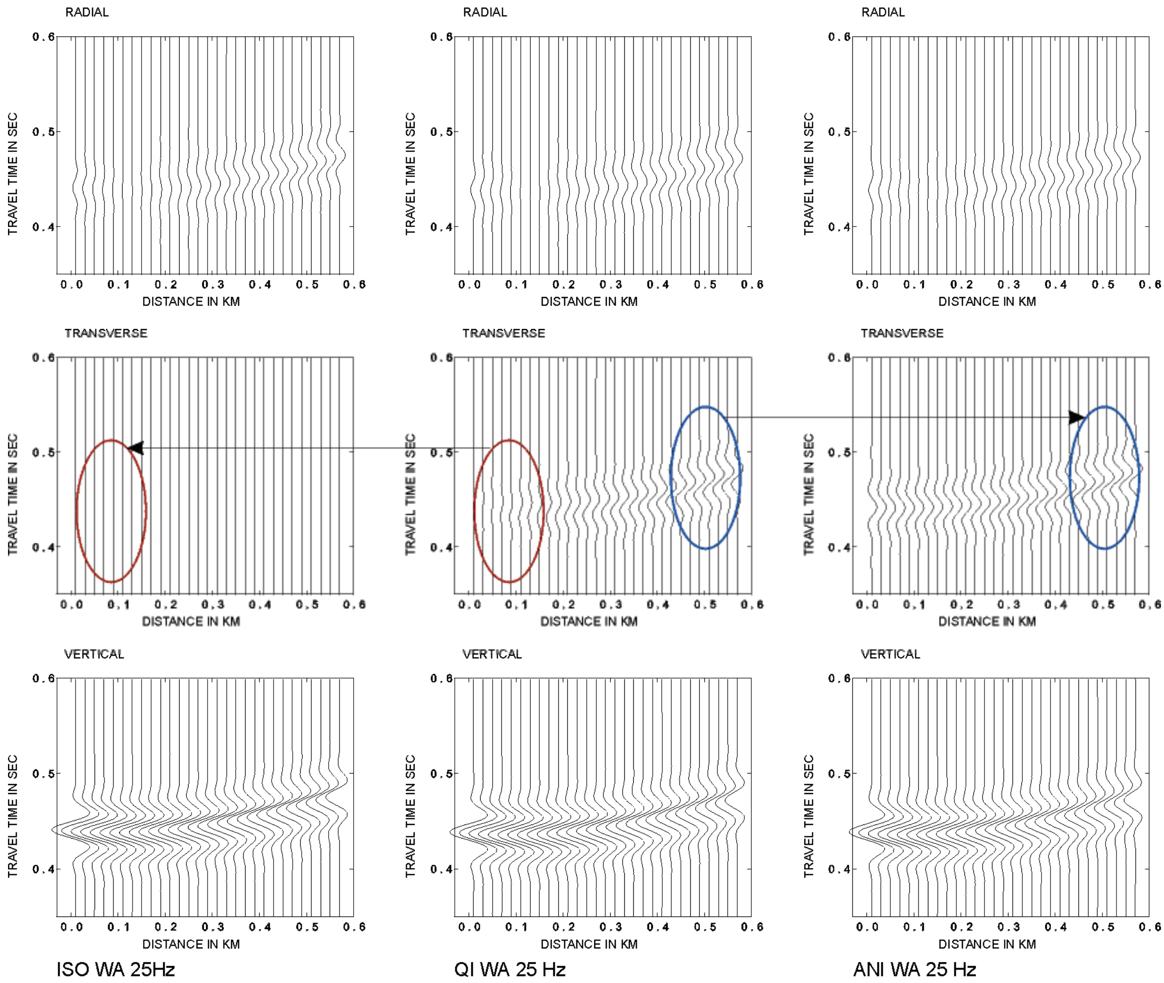

Fig. 15: Synthetic seismograms calculated by the ray methods for isotropic (ISO) and anisotropic (ANI) media and by the QI approach.

Seismotectonics and Geodynamic Evolution of the Northern Part of Andean South America
(granted by GAASCR A3012805)

Duration: 1998-2000
Principal investigator: Václav Hanuš
Co-workers: Jiří Vaněk, Aleš Špičák, Věra Vaňková, Alice Slancová

Deep Structure, Seismotectonics and Geological Evolution of Central and Eastern Indonesia
(granted by GACR 205/97/0898)

Duration: 1997-1999
Principal investigator: Aleš Špičák
Co-workers: Václav Hanuš, Alice Slancová, Jiří Vaněk

The activities concerning seismotectonics and plate tectonics were focused on the investigation of various aspects of deep structure of two active convergent plate margins: (1) the Indonesian island arc and (2) Andean South America. Research in the Laboratory of Global Tectonics and Metallogeny integrates seismological analysis with accumulated geological and geophysical knowledge acquired by partner institutions (Southeast Asia Research Group of the University of London, regular international symposia on Andean Geodynamics).

The catalogues of the International Seismological Centre (ISC) and specifically relocated ISC and NEIC earthquake data for the period 1964-95 were used for seismological analyses. Fault plane solutions of earthquakes from the list of Harvard centroid moment tensor solutions (HCMT) were applied to estimate tectonic regime in the downgoing slab and to verify strike, dip, and the character of faulting of individual fracture zones.

(1) Indonesian Island arc

Our activity in this region was concentrated mainly on the study of the deep structure of Java-Lombok and Sumbawa-Flores regions limited by the longitudes 104°-122°E. The area was covered by 50 vertical sections across the Java-Sumatra trench. It enabled to differentiate the earthquakes belonging to the Wadati-Benioff zone from those localised in the overlying Eurasian plate and those localised in the Indo-Australian plate in the vicinity of the Java-Sumatra trench.

In the Wadati-Benioff zone, the existence of an aseismic gap at depths of about 100 km was found and its spatial correlation with the position of active calc-alkaline volcanoes was established. All active volcanoes are situated directly above the aseismic gap and prove also in this region the concept on the source of primary magma for calc-alkaline volcanism in the partially melted aseismic gap in the subducted oceanic lithosphere.

Earthquakes occurring in the continental plate overlying the subduction of Indo-Australian plate were attributed to several seismically active fracture zones. Their geometrical parameters (position and width of the trace, thickness, dip and maximum depth) were established by means of the distribution of earthquake hypocentres and verified by fault plane solutions. The spatial correlation of the position and orientation of the seismically active fracture zones in Sumatra and Java-Lombok regions with the occurrences of main hypogene mineral deposits point to the fact that practically all important mineral deposits are situated in the outcrops of these fracture zones. It is evident that active fracture zones, penetrating the whole thickness of the continental lithosphere, effectuate channelling of ore-bearing solutions liberated from the subducting oceanic lithosphere.

(2) Andean South America

In the area which is roughly bounded by latitudes 17°-23°S, the Peru-Chile trench changes its strike from the azimuth of 150° to 190° (the Arica Elbow region). A finger-like shape of the lower part of the Wadati-Benioff zone beneath the aseismic gap was established in this region. The slab length is stable (around 350 km) to the north of the region, varies expressively between 350 and 750 km in the Arica Elbow region and is stable again south of the region (650 km). The dip and thickness of the Wadati-Benioff zone are practically constant in all sections.

Nine seismically active fracture zones were delineated in the Arica Elbow region. Existing fault plane solutions were attributed to the pertinent fracture zones and confronted with their orientation, inclination and tectonic function. The analysis shows normal faulting in the eastward dipping fractures, bordering the Andes in the west, and reverse faulting in the westward dipping fractures, limiting the Andes in the east. The position, inclination and stress conditions in the westernmost fracture system might influence the shift of active volcanism westward from the surface projection of the intermediate depth aseismic gap in the Wadati-Benioff zone and cause the channelling of magma through tectonically disintegrated seismically active fracture zones.

The spatial correlation of the position of seismically active fracture zones in the central part of the Andean South America between 18° and 34°S with the distribution of hypogene accumulations of metals revealed that the majority of large deposits and mining districts are situated in the outcrops of these fracture zones. The geometrical documentation of the most important fracture zones and data on mineralogical composition, genetic type and available radiometric ages of mineral deposits were presented in several maps and tables. The mining districts with dated mineral deposits were arranged into four periods of endogenous mineralization which correlate well with four supposed Andean subduction cycles active in the Tertiary. The occurrence of mineral deposits of different age in recently active fracture zones (Fig. 16) can be used as an important criterion in favour of long-term spatial permanence and activity of these zones and as a guide for the discovery of further mineral deposits hidden under young sedimentary and volcanic cover.

The stress in the Wadati-Benioff zone was determined. The state of stress tends to change more systematically with its depth than laterally and seems to be connected with the morphology of the Wadati-Benioff zone. Fault plane solutions show that thrust faulting occurs in the depth range 0-100 km at the vicinity of the convergent boundary. In the remaining parts of the Wadati-Benioff zone, normal faulting predominantly occurs including the belt of deep earthquakes.

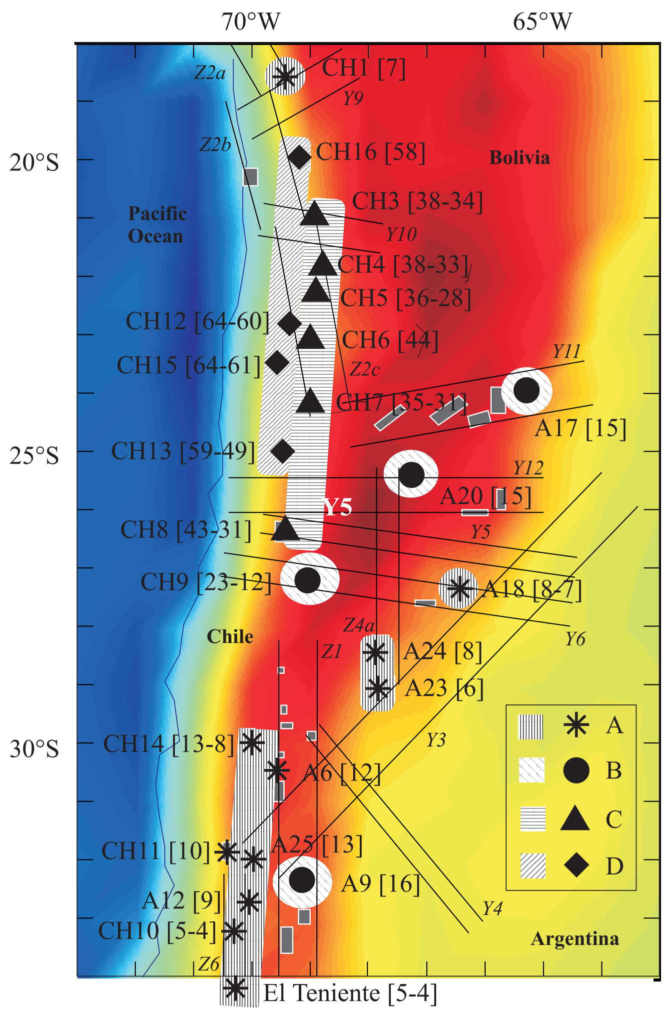

Fig. 16: Distribution of metallogenic belts and mineral deposits of different age in the framework of the seismically active fracture zones. Ages in MA are given at individual mining districts in brackets; A – Upper Miocene – Pliocene, B – Upper Oligocene – Middle Miocene, C – Upper Eocene – Middle Oligocene, D – Lower Paleocene – Upper Eocene.

Velocity Distribution in the Bohemian Massif and Fast Localisation of Regional Earthquakes from Broadband Seismological Observations (granted by GACR 205/98/0858)

Duration: 1998 – 2000

Principal Investigator: Jan Zedník

Co-workers: Bohuslav Růžek, Axel Plešinger, Josef Horálek, Jiří Pospíšil, Jiří Soukup

The aim of the project is to study the velocity distribution of seismic waves in the Bohemian Massif from digital records of regional earthquakes recorded by the Czech National Seismological Network. A considerable number of broadband records of regional seismic events were accumulated over decades. A detailed analysis of events from the region of Ostrava, Opava and the Jeseniky Mts., Hronov and Western Bohemia as well as from the Alps and the Carpathians and mining regions of Kladno, Upper Silesia and Lubin will be carried out. Regional velocities of individual observed seismic phases and their azimuthal dependencies will be derived to improve currently used regional travel-time tables and localisation procedures. Comparison of synthetic and observed broadband seismograms will help to derive the velocity model of the Bohemian Massif, which will be subsequently used for fast localisation of local and regional events. Advanced software for near-real time broadband data processing will be implemented and co-ordinated at the GI and IPE data centres. A unified local magnitude scale will be applied and a joint bulletin of earthquakes originated on the territory of the Czech Republic will be published. The results of the analysis of regional events will be made accessible on Internet for other geophysical institutions, universities, and the public.

The effort in 1998 was concentrated mainly on the following goals:

- Continuous data flow of broadband signals from seismological observatories Dobruška/Polom in NE Bohemia and Nový Kostel in the region of earthquake swarm in Western Bohemia was established.
- Digital data acquisition system Vistec and broadband seismometers Kirnos were installed at seismological station Ostrava / Krásné Pole.
- Broadband records of regional earthquakes were selected from the digital archive of the Geophysical Institute and converted to a common data format.
- Advanced analysis programs for routine data processing were installed on UNIX workstations. Linux-based programs for preprocessing and format conversion of continuous broadband data from different stations and a data acquisition system were developed in the frame of the grant project.
- A 1-D velocity model with azimuthal dependence was developed for the swarm region of Western Bohemia. Derived velocities will be used as a starting model in the study of velocity distribution in the Bohemian Massif.

Numerical Modelling of the Geodynamo
(granted by GACR 205/97/0897)

Duration: 1997-1999
Principal investigator: Pavel Hejda
Co-workers: Ivan Cupal

2,5-D Model of the Geomagnetic Field Generation
(granted by GA AV CR A3012707/1997)

Duration:1997-1999
Principal investigator: Ivan Cupal
Co-workers: Pavel Hejda

Although the existence of the magnetic field of the Earth has been known for centuries, it is only in the past few decades that we have begun to understand its origin. It is now generally accepted that the field is created by the dynamo action of convective fluid in the conducting outer core of the Earth. The great progress in understanding of these processes has undoubtedly been achieved with the aid of numerical modelling. In the last period three dimensional models have been developed that simulate the magnetic field generation in a fluid outer core with physical properties very similar to those in the Earth's core. However, two parameters lack a realistic value in the models: the kinematic viscosity, or, by other words, a thickness of the boundary layer which is closely related to the viscosity and the temperature gradient within outer core. While the larger temperature gradient used in the models is rather connected with certain simplification in thermodynamics the problem with boundary layers is numerical. As very thin layers cannot be treated numerically, the viscosity was usually taken of about four to six orders higher than its real value in the Earth's core. The only way to avoid these difficulties is to resolve the boundary layers analytically.

This alternative approach was developed in the frame of our recent grants. Two-dimensional (2D) mean-field models with a freely rotating finitely conducting inner core were solved. Due to the solid inner core one has to treat not only the boundary layers, but also the so called Stewartson layer on the cylinder circumscribing the inner core and parallel with the axis of the rotation. It is well known that discontinuity across the Stewartson cylinder takes place in the absence of viscosity. Nevertheless, our results have confirmed that a sufficiently strong magnetic field suppresses this discontinuity. An approximation of very small viscosity by zero viscosity was unsuccessful in 2D-models. Surprisingly the solution depends on the viscosity. Generation independent of core-mantle coupling must be sought in fully 3D models.

Extension of this approach to the general three-dimensional case is a rather complicated problem. The first step of this approach assumes no inner core to avoid problems with Stewartson layer and we solve Ekman core-mantle boundary layer analytically. Moreover, we use a mean-field approximation where each quantity is expanded into large axially symmetrical part and a smaller non-axisymmetrical part. This enables us to formulate the set of equations for symmetrical quantities separately from non-axisymmetric set where small interactions between non-axisymmetric quantities can be neglected. This simplification enables us to save a time necessary for the processing on computers. As the higher order interactions in magnitude are only taken into account we can allow ourselves to approximate the third dimension (azimuth) by only several first harmonics in a Fourier expansion (2,5-D model). This approach enables us to solve models using more common computers (PC-Pentium) than fully 3D-models, however, the simplification does not make possible to deal with small scale phenomena.

Use of Soil Magnetometry in Mapping Industrially Polluted Areas
(granted by GAASCR A3012605/1996)

Duration: 1996-1998
Principal investigator: Aleš Kapička
Co-workers: Eduard Petrovský, Karel Zapletal (AGICO, Brno)

Magnetic Identification of Industrial Pollution of Present and Recent Alluvial Formations
(granted by GACR 205/96/0260)

Duration: 1996-1998
Principal investigator: Eduard Petrovský
Co-workers: Aleš Kapička, Karel Zapletal (AGICO, Brno)

Magnetic Mapping and Analysis of Contaminated Recent Soil Sediments
(granted by GAASCR A3012905/1999)

Duration: 1999-2002
Principal investigator: Aleš Kapička
Co-workers: Eduard Petrovský, Neli Jordanova, Vilém Podrázský (Czech Agricultural University, Prague)

Investigations of magnetic properties of present soils and present and recent sediments represent a new and emerging field of application of rock magnetism – present environmental magnetism. Apart from primary ferrimagnetic minerals, present sediments and soils contain also minerals, such as magnetite, of anthropogeneic origin, transported to the sediments via, e.g., atmospheric deposition of fly ashes, produced mostly during burning fossil fuel. These magnetic (mostly magnetite) particles exhibit specific morphology and magnetic properties and concentrate particularly in OF soil subhorizont. Therefore measurements of magnetic parameters reflecting concentration of ferrimagnetic minerals, such as magnetic susceptibility, can be used in estimating the increased levels of industrial pollution in soils or sediments.

In our study, effectiveness and limitations of soil magnetometry were tested on an area affected by a significant and relatively isolated pollution source – the brown-coal burning power plant at Počerady. Detailed magnetic mapping of soils was carried out over the area of about 30 km around the power plant. Despite significant decrease of emissions, the power plant still contributes to air pollution

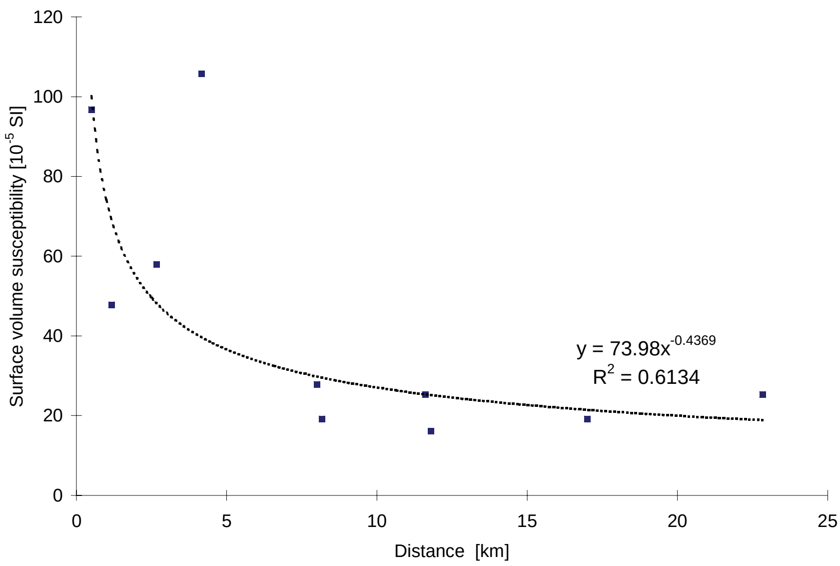

Fig. 17 Magnetic susceptibility at different distances in the southward direction. Steep decrease with increasing distance is typical for isolated sources of anthropogenic pollution.

by annual discharge of about 400 tons of fly ashes (data from 1997). Magnetic properties of this material have been studied in detail. Field mapping around the power plant showed that the most magnetically enhanced soil layer is in depth of 5-10 cm. High correlation between susceptibility values measured in laboratory and those acquired in field confirm that in situ field measurements are reliable enough. Distribution of the susceptibility values was not even around the source, and both radial and angular variations could be observed. While the north-east direction seems to be the most polluted, showing practically constant values of magnetic susceptibility, the southward direction exhibits rapid decrease of magnetic susceptibility with increasing distance from the source and at 10-15 km reaches its minimum values (Fig. 17). Thermomagnetic analysis, X-ray diffraction and scanning electron microscopy of fly ash samples suggest the presence of non-stoichiometric maghemitised ferrimagnetic phase, comprising some 10% vol. A corresponding magnetic phase can be identified also in polluted soil samples.

Other possible application of magnetic identification of pollution can be demonstrated on fluvisols contaminated with Pb, Cd and Zn, formed by a breakdown of basin-deposit of ashes from a lead-smelter in the town of Příbram. In this case, measurements of magnetic susceptibility followed up previous geochemical analysis. Good agreement was found between distribution patterns of magnetic susceptibility on one side and concentrations of Pb, Zn and Cd on the other in both the surface layer and layer at depth of 60 cm. Magnetic susceptibility distribution discriminates clearly the polluted fluvisols from non-polluted soils, located above the pollution source (Fig. 18). Good results were also acquired on river sediments from upper part of Vltava River. In this case, lithogenic contributions can be neglected and the effect of minor, isolated local sources such as paper mills or public boilers can be easily detected using simple and fast measurements of magnetic susceptibility of stream sediments.

A new project, commenced in 1999, is aimed at determining the extent of pollution due to atmospheric deposition of solid particulates on a regional scale (Giant Mountains National Park). The project is carried out in co-operation with the Czech Agricultural University and the Research Institute of Forestry and completes similar studies carried out by Polish colleagues on the other side of the border. A set of 38 soil-profile pits has been investigated magnetically during the first year of the project. First results show clearly dominant accumulation of anthropogenic ferrimagnetics in OL to OF soil subhorizons. These layers are characterised by maximum of low-field magnetic susceptibility (k) and very low (2.5 %) frequency dependent susceptibility (k_{FD}). Practically in all soil profiles investigated the lithogenic effect on magnetic parameters of topsoil horizons is negligible.

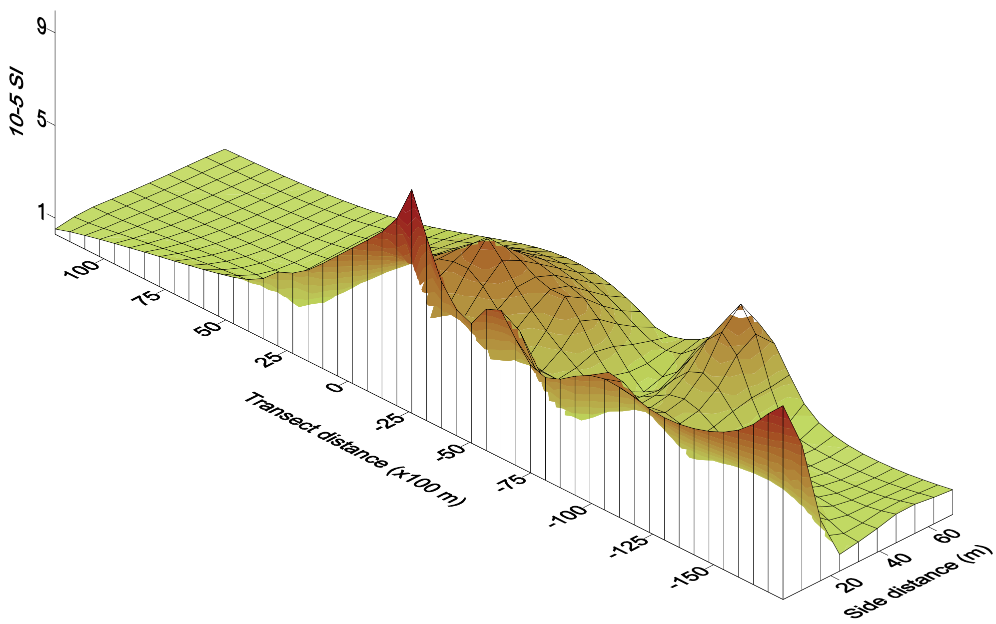

Fig. 18 Magnetic susceptibility of polluted fluvisoils along the Litávka river in the depth of 60 cm (downstream from the basin-deposit of ashes).

Extraterrestrial influences on the winter tropospheric circulation
(granted by GAASCR A3012806)

Duration: 1998 - 2001
Principal investigator: Josef Pýcha
Co-workers: Petra Šauli, Josef Bochníček, Václav Bucha

Tropospheric temperature and pressure fields as well as prevailing winds on the Northern Hemisphere in the winter period 1952-1996 were investigated. Composite maps created for high and low geomagnetic activity and individual QBO phases show clear differences not only between different levels of geomagnetic activity, but also between the two phases of QBO. Beside other things, the analysis of the composite maps showed (Fig.19):

1) There are such distributions of the meteorological fields in the lower troposphere, which are ‘typical’ of a given combination of the QBO phase and geomagnetic activity level.
2) Geomagnetic activity is an important and non-negligible correlator in ‘Sun-weather’ research.
3) *High geomagnetic activity*, during the *QBO-east phase*, is associated with the strengthening of zonal flow over north-eastern Europe; during the *QBO-west phase*, it is associated with the strengthening of zonal flow over the northern Atlantic.
4) *Low geomagnetic activity*, during the *QBO-east phase*, is associated with the weakening of zonal flow over Europe and the northern Atlantic; during the *QBO-west phase*, it is associated with the weakening of zonal flow over Europe and the development of meridional flow over the northern Atlantic.

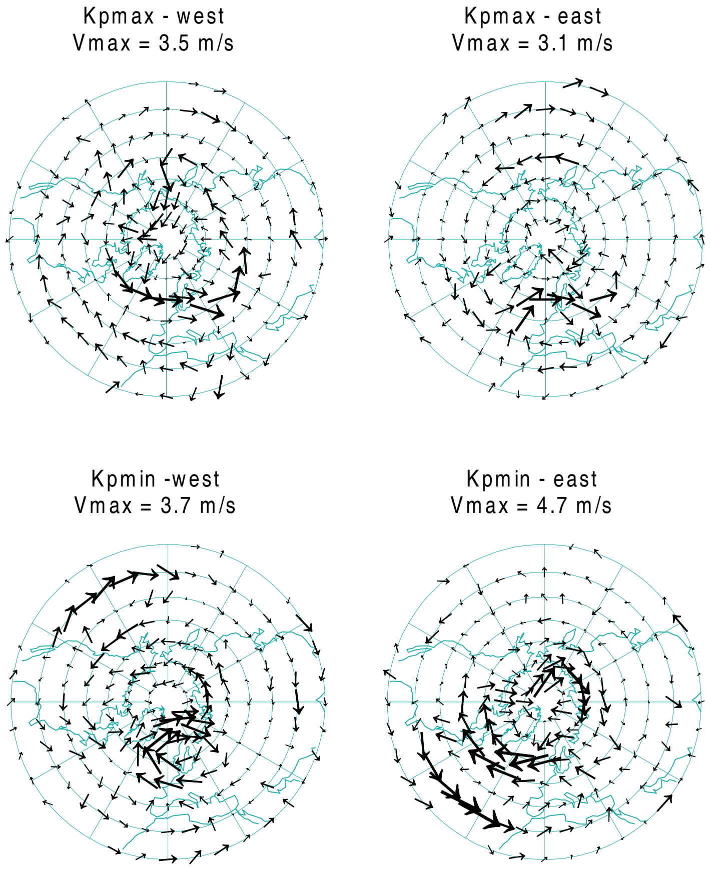

Fig. 19 Deviations of winter mean wind 850 mb.

Climate Change of the Past 300 Years Inferred from the Analysis of the Underground Temperature Field (granted by GACR/205/96/0969)

Duration: 1996-1998
Principal investigator: Vladimír Čermák
Co-workers: Jan Šafanda, Milan Krešl, Petr Štulc, Lenka Kučerová, Robert Kincler

Ground surface temperature changes penetrate into the Earth's subsurface and the high-frequency component of the transient temperature signal is progressively filtered out as it propagates downward. The temperature field at a depth of several tens to several hundreds metres thus contains a record of long-term ground surface temperature (GST) variations. This information can be recovered from borehole temperature profiles that allow reconstruction of the GST-history of several past centuries. Altogether ninety-eight T(z)-profiles, originally measured for heat flow determination on the territory of the Czech republic, were carefully selected and analysed. Climatic episodes over the past two millennia were identified, including warmer period around 400 A.D., followed by colder times between 700–1000 A.D., the Little Climatic Optimum with its culmination around 1250±50 A.D., and the Little Ice Age with temperature minimum at 1650±30 A.D.

Since the beginning of the 19th century a general warming has dominated the climatic pattern only interrupted by several short-term oscillations. Our results were compared with the annual mean surface air-temperature (SAT) records from the meteorological stations in Prague-Klementinum, Munich and Vienna. The relatively warmer period around 1820 with a subsequent cooling appears in all these records, also the 1880's were the coldest decade. Similarly the warmer 30´s and colder 40´s of the 20th century seem to be well confirmed. Practically all boreholes yielded GST histories that exhibited a significant recent warming that started only a few decades ago. To assess the geographical distribution and evaluate a possible man-made industrial contribution the rate of temperature change since 1950-60 has been calculated individually for each borehole and all obtained data were averaged in a regular 1x1 degree latitude-longitude grid network. Most of warming rates in the period 1960-1995 exceed their standard deviations, and amount to 1-1.5 K, which is significantly more than the earlier climatic excursions. There is a good agreement with the SAT-trends recorded in the nearby meteorological stations. Warming has been particularly intense around Prague and in its vicinity (over 2 K/100 yr.) and decreased to the south and south-west. The most western part of Bohemia shows inexpressive cooling. Another area of significant recent warming of 2.6-2.8 K/100 yr. corresponds to the industrial regions of Sudety and Ostrava coal basins. The lowest warming of 0.07 to 0.6 K/100 yr. were found in south-western and southern parts of the Bohemian Massif, areas generally forested. To verify the obtained climatic history, the instrumental records of mean annual air-temperature (1960-95) from 30 meteorological stations were used to construct the similar pattern of recent climatic change. Both maps gave good agreement, with the exception of the western Bohemia, where meteorological data suggested warming rather than cooling, the fact so far not satisfactorily explained, but probably related to highly variable altitude of the existing borehole sites in westernmost part of the Krušné Hory Mts.

The recent climate trend thus seems to be rather complex and cannot be attributed entirely to the long-term global warming phenomenon. While a substantial part of it can be explained as simple natural short-term oscillation related to the return of climate from the previous colder conditions of the 17-18th centuries back to 'normal', certain part of observed temperature increase indicates potential human impact on climate. Urban growth and industrialisation, just as deforestation and consequent land development and/or change in vegetation cover, may contribute to warming and produce smaller or larger regional anomalies.

Climatic Changes in the Past Derived from Borehole Temperature Inversion and Correlation with Meteorological Data (granted by GAASCR A3012706)

Duration: 1997 - 1999

Principal investigator: Milan Krešl

Co-workers: Vladimír Čermák, Lenka Kučerová, Jan Šafanda

Any climate change is accompanied by corresponding variation in the ground surface (soil) temperature. From the theory of heat conduction the temperature changes at the surface propagate into the subsurface with an amplitude attenuation and time delay that increase with depth. The inversion of the existing temperature-depth records can, under favourable conditions, provide valuable information on the ground surface temperature history of the past several hundred years.

To find out the temperature history of the territory we processed data from 30 meteorological stations in the Czech republic. The data collection covers daily measurements (at 7 am, 2 pm, 9 pm} in five depth levels (5, 10, 20, 50, 100 cm) and 200 cm above surface. During data processing it was necessary to substitute missing data by an appropriate approximation. With respect to the long term course and regional deformation of the temperature records we applied a periodical curve

$$T = a + b\omega t + c \sin(\omega t + \varphi_1) + d \cos(2\omega t + \varphi_2),$$

where T is the current temperature on the day t, a is the annual mean temperature, b is the mean annual increment of temperature, c is amplitude of the first harmonic, φ_1 is its phase shift, d is amplitude of the second harmonic, φ_2 is its phase shift.

The basic harmonics represents the annual periodicity of temperature, the second harmonics expresses the slope of the spring temperature increase and the autumn temperature decrease, thus shifting the summer maximum and winter minimum. We distributed the temperature recordings to several classes: Symmetrical, with the maximum approximately in the middle of the year (1965, 1982) and asymmetrical with the summer maximum lying closer to spring (1964, 1976, 1979) or closer towards to autumn (1974, 1985). At each station we calculated the annual mean temperature and the mean temperature for each quarter, separately for the morning, noon and evening measurements. These mean temperatures served for calculation of the temperature trend at all the stations during the investigated period 1961 - 1990. We studied both the annual and quarterly trends. From the collection of stations processed thus far, the following information has been derived:

Major maxims of the thirty years means of both the air and soil temperatures were achieved in the years 1968, 1975, 1983, 1989. In contrast, cooler years were in 1962, 1965, 1970, 1980, and 1985. Moravian stations are of greater scatter than the Czech ones. The station at Cheb seems to be the quietest. The quarterly division of years enables us to make a more detailed analysis of the temperature distribution development for different characteristical seasons.

Currently we are processing the data of Europian stations (source: NOAA database) with long term recordings in order to find out areas with the same or similar trend of climate development. By now, according to similar temperature course, we divided Europe into four belts: Scandinavia, North Europe, Middle Europe, South of Alps.

It is necessary to complete the current data set with further hydrometeorological data, as precipitation, snow layer etc.

The Department of Geothermics is continuously monitoring temperature in special boreholes in Praha and Kocelovice (about 100 km SW of Praha). Frequency of reading is 2 hours^{-1} at 22 depth levels between surface and 40 meters as well as in 3 levels above surface. Monitoring of precipitation, wind speed and direction, soil moisture, snow layer and sun radiation is being prepared for running.

Thermal History of the Sedimentary Basins of the Czech Republic and its Relation to Tectonic Processes (granted by GAASCR A3012703)

Duration: 1997-2001

Principal investigator: Jan Šafanda

Co-workers: Vladimír Čermák, Robert Kincler, Milan Krešl, Lenka Kučerová, Petr Štulc, Věra Vaňková

Co-investigators: V. Suchý (Geological Institute ASCR, Prague), I. Sýkorová (Institute of Rock Structure and Mechanics ASCR, Prague), M. Stejskal (Institute of Chemical Technology, Prague)

The five-year grant addresses the present and past thermal conditions in selected sedimentary basins of the Czech Republic. The thermal history of sedimentary rocks is being studied by a few independent methods, which will provide the quantitative data on the maximum temperature experienced by the rock, possibly on the timing and pressure conditions. The methods are based on the organic mater maturation, the illite crystallinity and the fluid inclusions. Investigation of present conditions comprises temperature logging in boreholes, estimation of thermophysical properties of rocks and mathematical modelling of the heat transfer. It focuses on the Lower Palaeozoic Barrandian Basin and on the basins of the Ohře Graben and the adjacent area. The important part of this research consists in investigating the present conditions, which provide, especially in case of the recent basins, the possibility of calibration paleogeothermal methods.

A large set of rock samples was collected during the first two years of the project from the sedimentary fill of the Barrandian Basin, which was studied by the above mentioned method. The spectrum of the methods was enlarged by the fission track analysis on the apatite crystals. The first results suggest that the Lower Palaeozoic sediments experienced a complex temperature history with at least two sudden thermal pulses. They could have been related to Silurian synsedimentary volcanism or to the emplacement of the Variscan Central Bohemian Pluton. The effect of the pluton formation on the adjacent rocks was assessed by simulation of the intrusion cooling, when the unsteady-state heat conduction equation was solved numerically in a 2-D geothermal model crossing perpendicularly the basin and the pluton. In order to obtain an upper estimate of the heat pulse, we assumed latent heat of magma crystallisation 315kJ/kg and its gradual liberation between the initial temperature of 800^{o}C and the temperature of the final solidification 700^{o}C. It turned out, however, that the distance between the basin and the pluton, 15 km and more is too large for the direct influence of the sediments by the intrusion heat. But it is probable that the processes leading to the pluton formation affected the geothermal regime on the regional scale and could have increased the amount of heat coming to the basin through its basement and consequently the temperature of the sediments. The assessment of these effects is a question for future studies.

The same methodology was used in assessing the thermal conditions of the contact metamorphism of Silurian black shale by basaltic, 4 m thick sill observed in the Kosov quarry in the Barrandian Basin. The zone of heating by more than 120^{o}C, which was the minimum temperature experienced by the sediments during their subsequent burial, is limited for the intrusion temperature 800^{o}C to a few metres around the sill.

Spatial and Temporal Changes of the Temperature Field in the Lithosphere of the Bohemian Massif (granted by GACR 205/97/0900)

Duration: 1997-1999

Principal investigator: Jan Šafanda

Co-workers: Vladimír Čermák, Robert Kincler, Milan Krešl, Lenka Kučerová, Petr Štulc, Věra Vaňková

Co-investigator: M. Kreidl (Czech Technical University, Prague)

The aim of the project is to improve our knowledge of the relationship between the geodynamic processes (uplift and erosion, volcanic activity), the long-term climatic changes (the ground surface temperature variations) and the present geological structure of the Bohemian Massif (inhomogeneities of the thermal conductivity and heat production, topography, groundwater migration), on the one side, and the time changes of the lithosphere temperature field and its spatial variability, on the other side. Special attention is paid to Northwest Bohemia. There is a number of partially or not at all interpreted temperature measurements here, which show a rather anomalous temperature-depth profiles. The project will result in a more precise picture of the lithosphere temperatures and the amount of heat coming from the upper mantle.

One of the studies carried out in frame of the project was the relationship between the mean annual ground surface temperature (GST) and the attitude of the surface. Variations of the GST extrapolated from 7 temperature-depth profiles measured in boreholes located in a forest in the Krušné Hory Mountains were related to the elevation and the slope attitude (angle and orientation) of the surface. A two-dimensional linear fit of the GSTs to the annual sum of the total sun radiation (obtained from the slope angle and orientation) and to the elevation yielded factors of 0.0040^{o}C/(kWh.m^{-2}year^{-1}) and -0.0040^{o}C/m, respectively. The latter factor is close to the value of -0.0047^{o}C/m found as the lapse rate of the annual soil temperature at the depth of 50 cm for the former Czechoslovakia. The GST variability due to the slope attitude amounts up to 1.1^{o}C in the investigated data set. This dependence was implemented into the computer code for routine calculations of the topographic corrections of the subsurface temperature gradient. Three-dimensional model calculations for a hilly terrain typical for the mountainous regions of the Central Europe revealed appreciable differences in distortion of the subsurface temperature field caused by considering or ignoring the investigated GST dependence on the slope attitude.

The activity was focused also on the northern part of the Bohemian Cretaceous Basin, where the subsurface temperature field was studied in a group of 8 boreholes drilled in a hydrogeologically active area (2 horizontally layered aquifers separated by an aquiclude) with a pronounced relief (400 m within 2 km from the borehole sites). In spite of relief the effect of topography was not identified: temperature at one altitude did not vary between the individual boreholes - the isotherms were nearly horizontal. This effect was simulated numerically along a 2D profile to assess the influence of horizontal water flow in the aquifers on temperature. The switch to the convective thermal regime occurred after an increase of permeability from 2.10^{-12} m^2 to 2.10^{-11} m^2. The water flow velocity was then sufficient to reduce lateral temperature variations induced by topography. The vertical temperature gradient in the aquiclude and the lower aquifer was not substantially affected by water flow and yielded the heat flow 90 - 100 mW.m^{-2}, which corresponds well to the increased heat flow observed in other parts of the Bohemian Cretaceous Basin.

Investigation of the Earth Using Geomagnetic Variations

(granted by the Italian Ministry of Foreign Affairs)

Duration: 1997-1999
Principal investigator: Václav Červ
Co-workers: Josef Pek, Oldřich Praus, Světlana Kováčiková

The main aims of the project are:

1. Performing and interpretation of the first magnetotelluric measurements in the seismoactive area of the Northwest Bohemia.
2. Modelling and interpretation of the long period magnetovariational measurements in central Italy

a) During 1997, a series of magnetotelluric (MT) soundings was carried out in the seismoactive region of Northwest Bohemia using Italian equipment and in collaboration with the staff of Italian partners. Fifteen MT stations were installed in an area of about 20 x 25 km^2 where 80% of the seismicity of the entire region has been recorded since 1986. The area showed a high electromagnetic noise, connected with the nearby industrial zone of Sokolov. The MT characteristics were studied and modelled by 2D and 3D techniques. The results (Fig. 20) show an extensive conductive structure in the depth range of 0.5 to 3 km. That could be connected with the presence of the locally buried granitic massif. Models considering the effect of these shallow structures can explain most of the features found in the high frequency experimental data. So far, it has not been possible to find any direct evidence of anomalously conductive structures at the focal depths. The results can be used as a first testing of MT results for the future measurements in this area.

b) New methods and algorithms for interpretation of magnetovariational measurements (2-D and 3-D forward modelling, thin sheet approximation and different inversions) were used for the interpretation of the long period magnetovariational measurements from the central Italy. The most evident common feature of the models is a deep conductive structure beneath the Apennines in the crust.

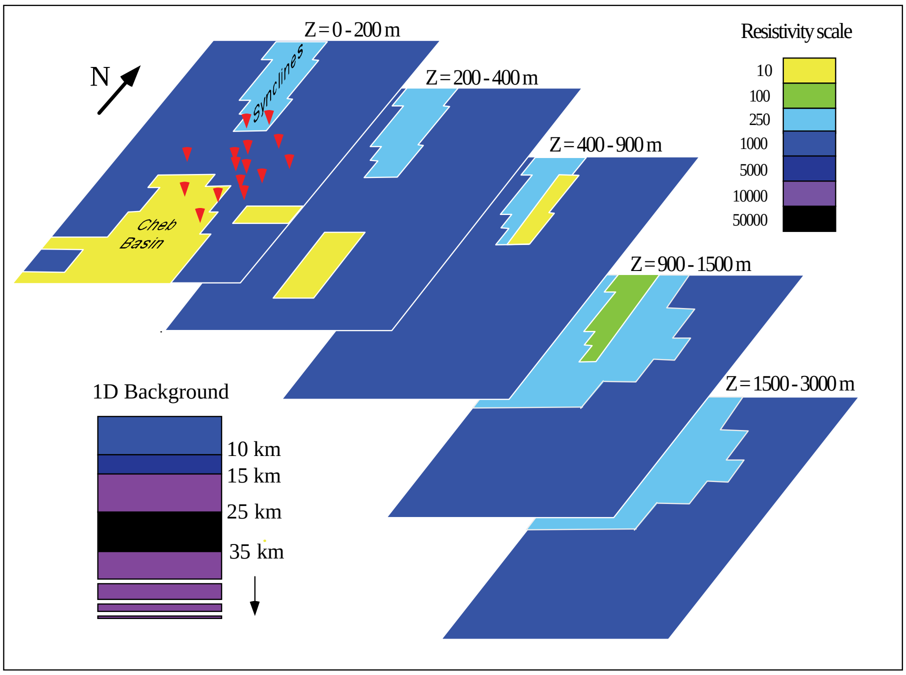

Fig. 20: Schematic 3-D geoelectrical model of the seismoactive area in West Bohemia.

Prediction of Climate Development in Central Europe: Implications from Solar Inertial Motion and Non-linear Analysis of Solar-Terrestrial and Climatic Time Series
(granted by GACR97/205/0921)

Duration: 1997 - 1999
Principal investigator: Ivanka Charvátová
Co-workers: Milan Paluš (Institute of Computer Science ASCR, Prague), Dagmar Novotná (Institute of Atmospheric Physics ASCR, Prague), Ladislav Kašpárek (Institute of Hydrology TGM, Prague)

A prediction of climate development in central Europe up to 2040 and further as ensues from solar motion computable in advance is the aim of this project. A verification of the original hypothesis of the principal investigator about a primary role of solar motion in a chain of solar-terrestrial (ST) and climate relations is needed for this purpose. Above all, the original finding - the separation of solar motion into two basic types, the ordered and the chaotic, which recur in the 179-yr cycle, will be used. The respective time series of the recent centuries will be processed in detail: A special attention will be focused on the interval 1850-1905, employing for prediction a similarity of the solar motion patterns in 1850-1905 and 1985-2040. Besides statistics and spectral analysis, above all modern methods for detection and classification of non-linear time series will be used for objective detection of different dynamical regimes and deterministic relations in ST and climatic recordings such as solar, geomagnetic and volcanic activities, surface air temperature, river flows, etc. The approach will enable us to distinguish between natural and anthropogenic parts of climatic change. An expected output of the project can manifest in estimation of natural environmental (living) conditions up to 2040.

Further two basic cycles in solar motion have been found: the shorter of 1.6 years in solar motion due to inner planets and the longer of 2402 years as the time distance between the 370-yr segments of the exceptional and nearly stable solar motion. The segments occurred in the years from 159 B.C. to 208 A.D., from 2560 B.C. to 2193 B.C. and from 4964 B.C. to 4596 B.C., etc., the next will occur within 2240 A.D. and 2610 A.D. (see Figure 21). As their response, the most stable parts of the 14C record are seen. The finding could enable us to predict solar activity for the next six centuries.

No relation between surface air temperature (global since 1861 and European since 1760) and solar activity has been shown. However, an occurrence of solar motion periodicity of 12-14, 10 and 8 years have been verified in temperature series by means of modern methods of analysis.

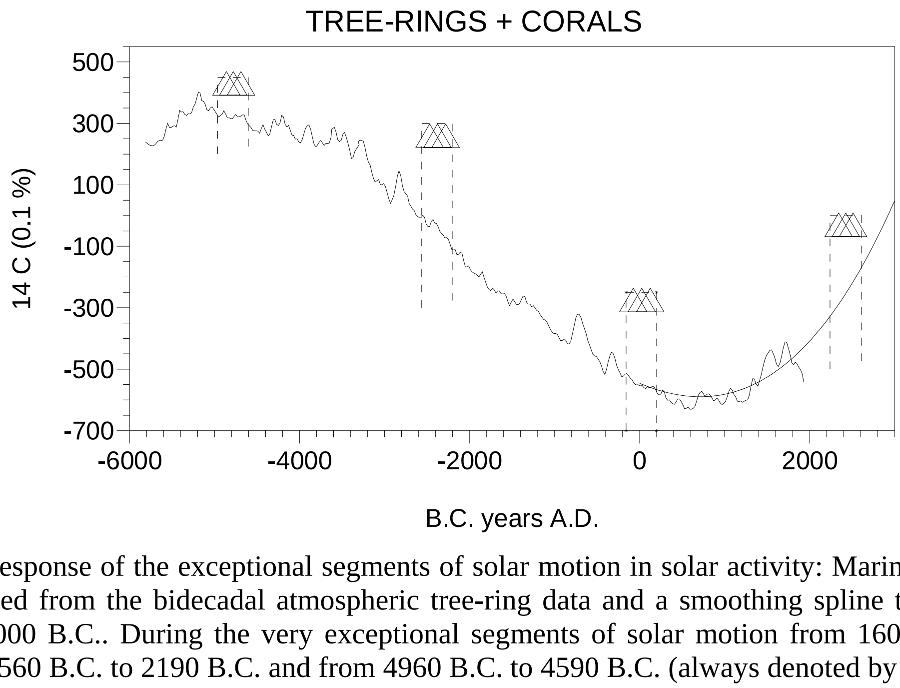

Fig. 21: A response of the exceptional segments of solar motion in solar activity: Marine model 14C ages calculated from the bidecadal atmospheric tree-ring data and a smoothing spline through coral data since 6000 B.C.. During the very exceptional segments of solar motion from 160 B.C. to 210 A.D., from 2560 B.C. to 2190 B.C. and from 4960 B.C. to 4590 B.C. (always denoted by vertical lines and by three triangles), permanent approximate stability of solar activity is seen. The same type of record could be predicted for the next exceptional segment of solar motion, which will occur within 2240, and 2610 A.D.

Electrical Conductivity at Crustal and Upper Mantle Depth over Central Europe with Emphasis to the Czech Republic (granted by GACR 205/95/1305)

Duration: 1995 - 1997

Principal investigator: Oldřich Praus

Co-workers: Zdeněk Martinec (Charles University, Prague), Václav Červ, Světlana Kováčiková, Josef Pek, Jana Pěčová

The project was aimed at refining model of the depth and lateral distribution of the electrical conductivity across the territory of the Czech Republic and of adjacent regions at depths from a few km to uppermost mantle depths of the order of 100 to 200 km. Methods of magnetotelluric (MT) and magnetovariation (MV) deep soundings were applied. The research involved:

i) spectral analysis of experimental data representing temporal variations of the natural electromagnetic field components at several stations (Fig. 4, in Geoelectric Dept.) by *applying new methods that enable us to apply tensor approach* in converting spectra of field components to different types of frequency dependent transfer functions;

ii) theoretical research oriented at *solving forward and inverse problems for the global model of 3-D inhomogeneous distribution of the electrical conductivity in the spherical Earth.*

New analysis of MT /MV data at 12 field stations along the profile of deep seismic sounding (DSS) No.VI, supplemented by data obtained at 3 additional stations occupied during the project, extended the previous set of results by new statistical estimates of amplitudes and phases of all MT impedance tensor elements. Rotating the co-ordinate system, we aimed at estimating the principal directions of resistivity tensor and corresponding resistivity and phases curves for further interpretation. Analysing the results, we find the principal directions weakly expressed, specifically in the Bohemian Massif (BM) indicating that it does not correspond to a well defined 2-D inhomogeneous structure. It is also characterised by a strong anisotropy of resistivity tensor. A 2-D character of the medium, however, does increase towards the SE. In general, the principal directions tend to align with SW-NE or NW-SE azimuths in correspondence with dominating tectonic elements of the BM. Combining previous results with those obtained by our recent analysis, we suggested a refined *model of geoelectrical cross-section beneath the DDS profile No VI* (Fig. 22):

a) There are three blocks with different geoelectrical structure: (i) consolidated relatively highly resistive block (resistivities 1000-200 Ω.m) of the BM; (ii) autonomous block of the transition zone between the BM and the West Carpathians (WCP); (iii) the Pannonian block of the inner Carpathian basin.

b) Layers of decreased resistivities are suggested at crustal and crust-mantle boundary depths different by individual geoelectrical units. In the Pannonian block we assume a layer (I) with resistivities between 10 and 20 Ω.m at depths between 10 and 18 km. In the BM layer (I) is suggested under the NW part of the profile starting approximately from the region between MT localities SE and MR, where its depth is about 40 km. The layer with resistivities between 400 and 500 Ω.m dips to about 40 km depths north-westward.

c) The structure of the transition zone is specific. We assume its north-western margin between the stations MR and SE (reversal of induction vectors, see further). The crustal layer (I) assumed here at 15-25 km depth, submerges, at the same time thickens from 10 to 50 km and, simultaneously, becomes more conductive with resistivities that decrease from 50 to 1-2 Ω.m progressively from the NW margin toward the WCP. A highly conductive slab submerging beneath the WCP unit represents an important feature of the model. It is the source of induced anomalous field mapped by reversals of induction vectors at several other profiles across the whole Carpathian region (see further).

d) The MT results reveal also a well-developed asthenosphere in the inner Carpathian region (stations SR, GB and MT results in Hungary) at depths between 80 and 100 km. Its resistivities are estimated to 5-10 Ω.m. The MT results suggest its submerging under the transition zone to depth over 150 km and, simultaneously, decrease of integrated conductivity characterising a poor stage of its development.

The variation data at all MT stations and further data of several field campaigns organised across the WCP region and, recently within the KTB project, were also used to estimate induction parameters relating the variations in Z (vertical) component of the geomagnetic field with its horizontal components H and D. Resulting transfer functions (TFs) are presented at each station as induction vectors. Reversals of their azimuths and strong changes of their magnitudes mark zones of anomalous induction (subduction zones, boundaries of geological units, fault and collision zones etc.). Estimates of induction vectors are available at more than 200 field sites across the Czech and Slovak Republics and almost 1500 induction vector estimates were collected across the Central European area. Contouring the induction vector components (TFs) at 150 field stations across the eastern margin of the BM and WCP, we find a *strongly anomalous belt at the eastern slopes of the BM (BMA anomaly) and another anomalous zone near the arc of the West Carpathian mountains (WCA).* The later zone is a part of the Carpathian geoelectrical anomaly as an important geophysical feature that marks the margin of the whole Carpathian lithospheric plate. Both anomalous zones are clearly seen in grey scale map (Fig. 23) displaying the module of the gradient of the real induction arrow azimuths across the area, and they seem to form a continuous belt connected in some way with the Trans-European Suture Zone traversing the territory of northern Germany and Poland. Both anomalous zones support also the interpretation of Brunovistulicum as promontory of the East European platform in position between the BM and WCP units.

To obtain a closer insight into sources and character of the anomalous induction we used the TFs to generate contour maps of internal vertical magnetic field components for different polarisation of a hypothetical external field across the entire region. Contour maps show that both anomalies are well defined by NNE and SSE polarisation of the inducing field, though the NNE azimuth is practically parallel with the strike of the BMA zone. Both types of polarisation suggest, thus, a strong influence of a conducting structure that is elongated in E-W direction, and of channelling by 3-D structures.

Anomalous vertical magnetic field generated by hypothetical horizontal field across array of stations suggests a method for generating maps of equivalent current stream functions at different depths. Smooth configuration of the current function contours can be obtained only for depths above the current sheet. If the depth exceeds the anomalous current source depth, instabilities appear in current function distribution in virtue of continuing the field beyond the source top level. Having generated equivalent systems corresponding to NE orientation (60^o) of inducing field for a series of different current sheet depths (Fig. 24, examples for 10 and 20 km depths), the *source depth is*

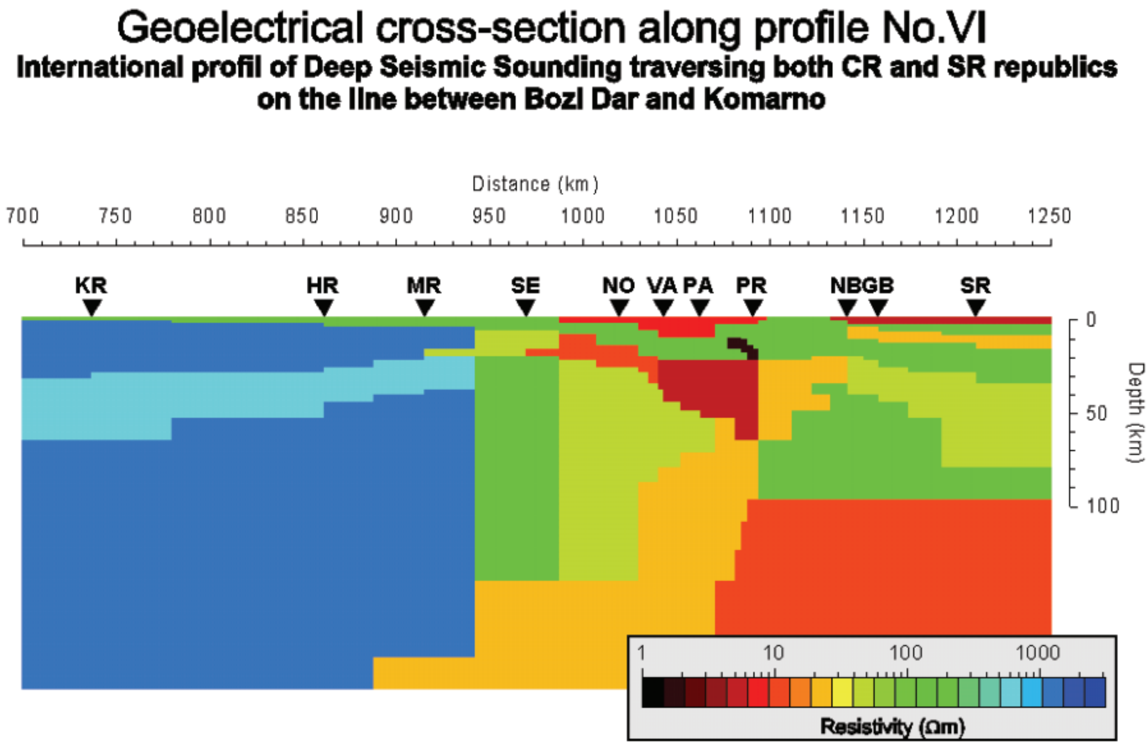

Fig. 22: Geoelectrical model along DSS No.VI.

concluded to be about 18 km in the WCP region and about 10-12 km in the BM/BV region.

The theoretical investigation was aimed at forward modelling of global geomagnetic response function for a 2-D conductivity structure of the upper mantle in the spherical Earth by spectral-finite element approach and its generalisation for 3-D models. The equations for electromagnetic induction within a 3-D spherical model were reformulated in a variational sense and resulting system of linear algebraic equations was solved by Galerkin method. Finally, the method and numerical code was tested and compared with the semi-analytical solution of electromagnetic induction of multiple eccentrically nested spheres. Converting a recent tomographic model of seismic velocities to a 3-D model of electrical conductivity by making use of the state equation relating the seismic velocities, temperature and electrical conductivity, we started preparatory steps to inverse modelling of geomagnetic induction for 3-D conductivity model of the upper mantle.

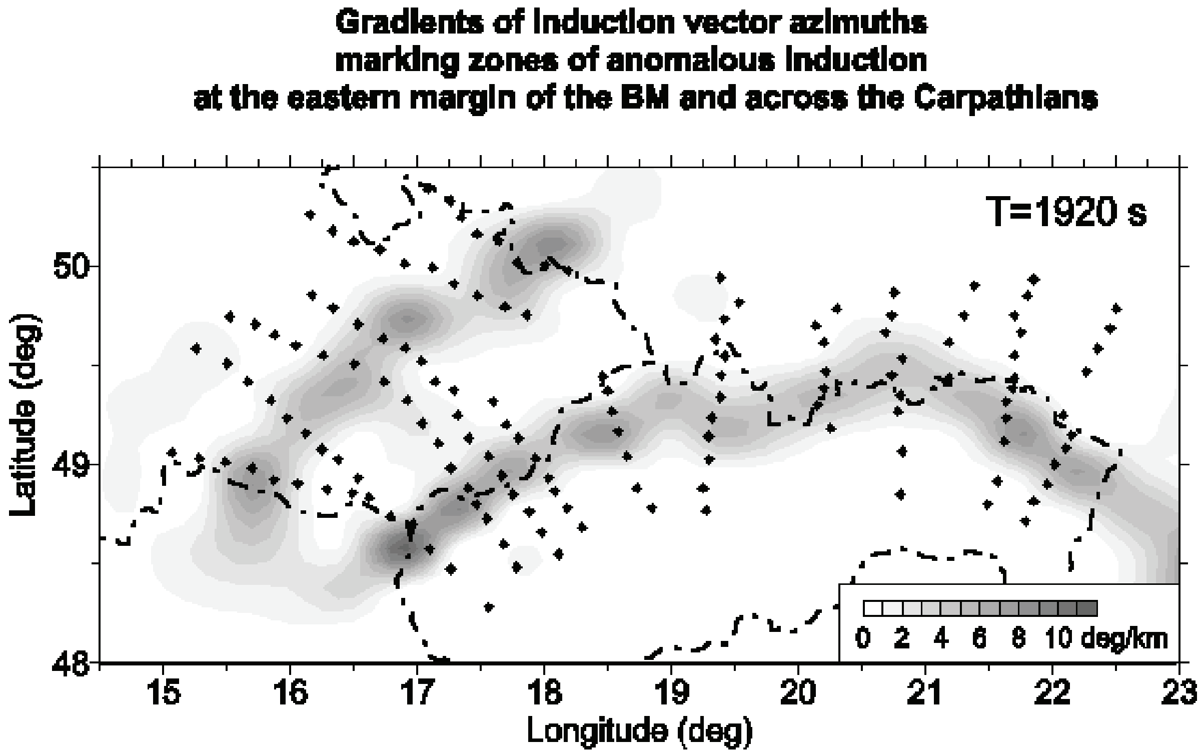

Fig. 23: BMA and WCA zones of anomalous induction.

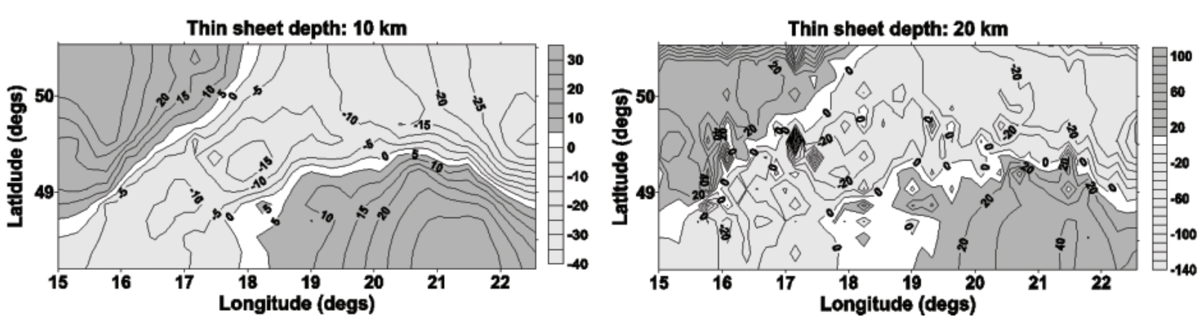

Fig. 24: Current stream functions (in A/km) for the period of 32 minutes for a thin-sheet embedded at depths of 10 and 20 km in a medium with conductivity of 0.001 S/m.

Electrical anisotropy within the Earth's crust - modelling and tectonic relations
(granted by GACR 205/99/0917)

Duration: 1999 - 2001
Principal Investigator: J. Pek
Co-workers: V. Červ, S. Kováčiková, O. Praus

Large-scale anisotropy of the electrical conductivity within the Earth's crust and uppermost mantle has been recently recognised as a real and significant attribute of deep geoelectrical structures, with evident relations to their tectonic setting. Besides the research into the structural, geological and tectonic mechanisms of generating the observed electrical anisotropies in the Earth, mathematical simulations of the propagation of electromagnetic fields in model structures with general anisotropy are of immense importance for both the anisotropy studies and geoelectrical data interpretations. The present project aims at developing and testing efficient and reliable methods and algorithms for modelling electric and electromagnetic fields in 2-D and 3-D horizontally inhomogeneous and generally anisotropic geoelectrical structures, as well as for inverting geoelectrical data for generally anisotropic 2-D conductivity distributions within the Earth. Studies on the effects of anisotropic structures on the surface data will contribute to specifying reliable indicators of deep anisotropic domains. The techniques developed will be used for the interpretation of anisotropic structures in a broader surroundings of the deep borehole KTB in Germany and in the western part of the Bohemian Massif, with special regard to the relation of the spatial extent of anisotropic layers to the tectonic model of the region.

In 1999, extensive testing of the earlier developed 2-D magnetotelluric (MT) modelling

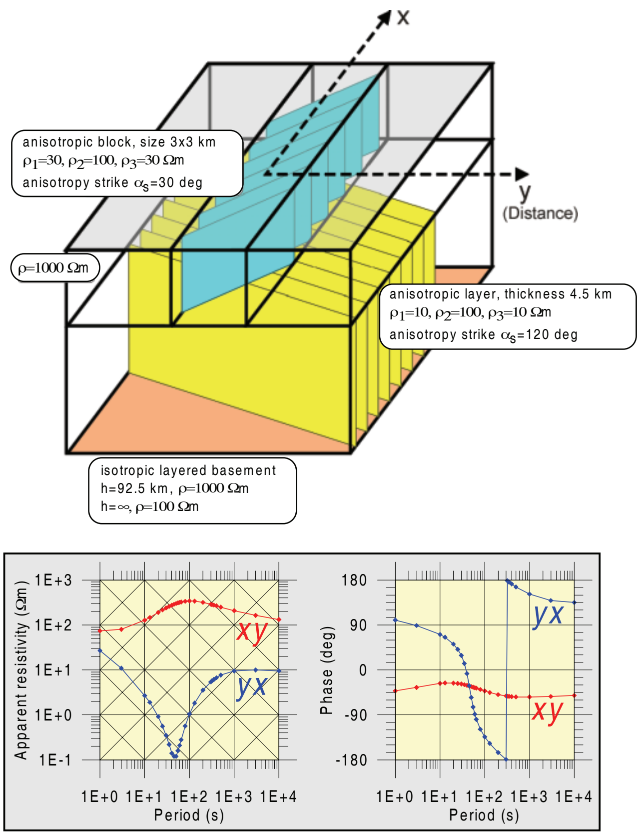

Fig. 25: Comparison of the finite difference and finite element modelling results for a 2-D model consisting of domains with different anisotropy strikes. *Top:* Schematic model setting. The lamelae symbolize the direction of the preferred conductivity within the individual subdomains. *Bottom:* Principal apparent resistivities and phases at the point situated above the center of the outcropping block. Full lines show the FE modelling results, points are for the FD results.

algorithm for anisotropic structures (Pek and Verner, 1997) has been carried out, aiming at *assessing the accuracy and reliability of the numerical modelling results for highly anisotropic models*. As no analytical results are available to test the numerical algorithms in the anisotropic case, comparative studies have been performed in co-operation with Dr. Y. Li and Prof. U. Schmucker from the University of Göttingen, Germany, based on using an alternative finite element numerical algorithm for modelling the MT field in 2-D anisotropic structures. In comparison with our finite difference procedure, the latter algorithm substantially simplifies the numerical approximation of the problem by homogenising the model throughout the non-conducting air and conducting earth domains, and, moreover, removes rather serious model size limits by applying an efficient iterative solver (preconditioned conjugate gradients for complex systems) to the normal system of the FE equations. In Fig. 25, we show the results of the comparison test for a model with highly distorting anisotropy effect on the MT curves. The model consists of a horizontally anisotropic layer that underlies an elongated outcropping anisotropic block. Directions of the preferred conductivity in the two anisotropic domains are perpendicular and general with respect to the structural strike of the model. Above the 2-D block, this configuration results in MT curves seriously violating the generally accepted rules of behaviour of the apparent resistivities and phases known from the isotropic models.

The finite difference modelling algorithm for 2-D generally anisotropic structures has been further *generalised to situations when both the bathymetry and topography have to be considered*. With perfectly insulating air, introducing a general topography leads to a FD matrix with a variable bandwidth, but standard flat-earth solvers can be still applied to this case with only a slight modification. Improved approach to evaluating the spatial derivatives of the basic field components, originally presented by Weaver for isotropic structures, has been re-formulated for the finite volume version of the FD approximation and corresponding *improved spatial derivative formulae have been generalised to anisotropic models*.

The methodological tools have been applied to the experimental magnetotelluric data from a broader vicinity of the German deep drilling project KTB with the aim to delineate in detail tectonically *significant anisotropic crustal structures in the western part of the Bohemian Massif*. The geoelectrical modelling of the data from recent cooperative German-Czech broadband MT measurements along a specially designed SW-NE profile from the KTB area to the Mariánské Lázně ultrabasite complex have proved that the high crustal electrical anisotropy extends across the whole Oberpfalz block, as far as the West Bohemian shear zone in the east, with deviated direction of the preferred conductivity (about E20°N) as compared with the Zone of Erbendorf and Vohenstrauß (E40°N to E50°N), where the KTB was drilled. The results also prove that the 10 km, E-W striking regional crustal conductor, which is required to explain the regional pattern of the induction arrows across the area involved, may be locally integrated with the anisotropic crustal block as its base with substantially increased principal conductivities.

Changes in the microstructure of the geomagnetic field during the total solar eclipse on August 11, 1999

(granted by GA CR 205/99/0915)

Duration: 1999 - 2000
Principal investigator: Jaroslav Střeštík
Co-worker: Karel Prikner

Some years ago a simultaneous measurement of geomagnetic Pc3 pulsation on the central European station net has been carried out with the aim to determine the dependence of pulsation periods on geomagnetic latitude. The aim of the present project was to repeat these measurements during the time of the total solar eclipse on August 11, 1999, and to use other observed data to judge the influence of the eclipse on the microstructure of the geomagnetic field. During the total solar eclipse the ionisation in the ionosphere and in the magnetosphere decreases for a time due to the shadowing. The conditions approach those in the night. This decrease of the ionisation affects the system of electric currents in the ionosphere responsible for diurnal variation of the geomagnetic field. It must reflect itself in the distortion of diurnal variation of geomagnetic field components and also in the mechanism of the origin and propagation of pulsation. Because total eclipses occur rarely, it is very difficult to collect a lot of data. Moreover, due to the fact that the path of total solar eclipse on the Earth's surface is different for different eclipses, many results may not be quite compatible with those received during some previous eclipses.

The eclipse in 1999 had an important advantage: it was observed in regions covered by a net of geomagnetic observatories which provide digital data with a step of 1 minute (normal-run data). Many of them (including our observatory Budkov) take part in the Intermagnet program and therefore their data are available for all other participants. Some observatories have equipment for recording geomagnetic pulsation digitally with a satisfactory time resolution (1 - 2 seconds, rapid-run data). To the end of 1999, a few months after the eclipse, only preliminary results can be presented. Normal-run data for August 9 till 13 are available from Hartland, Eskdalemuir (UK), Chambon la Foret (France), San Pablo (Spain), Fürstenfeldbruck, Niemegk (Germany), Brorfelde (Denmark), Belsk (Poland), Nagycenk, Tihany (Hungary), Surlari (Romania) and Kandili (Turkey). They cover a path of solar eclipse on the whole European continent. Some of these stations are situated a little to the North or South in the half-shadow zone. The overall geomagnetic activity was very low during August 10 - 12 so that possibles solar eclipse effect is not covered by other disturbances. An increase of the intensity in the EW component and less in the NS component is clear on all stations, even on those in the half-shadow zone. The position of this increase depends on the time of the eclipse, not on the UT, and is not observed in stations situated far from the eclipse zone (e.g. Fredericksburg, USA).

Rapid-run records are available (now, a few months after the eclipse) from Budkov and Nagycenk only. Preliminary analysis discovered a decrease in the amplitude of Pc3 pulsation lasting for about one hour and centred on the time of the eclipse. Pulsation in this time displayed a little different and unstable periods. Usually the pulsation period displays no changes during the day so that the observed effect could be connected with changes in the ionosphere during the solar eclipse. Rapid-run data from some other observatories as well as data with a finer time resolution (0.1 seconds, available from Budkov only) will be processed later.

Geophysical investigation in the regions with different degree of tectonic activity in Central Europe and Japan

(project NJ-23 in the program KONTAKT)

Duration: 1998 - 2002

Principal investigator: RNDr. Václav Červ, CSc.

The project has been oriented to the development of new numerical methods, algorithms and computation programs that are suitable for the interpretation of the magnetotelluric and magnetovariational measurements. The different methods developed in the Czech Republic and in Japan are compared and tested on the experimental data sets from regions with different degree of tectonic activity and the most suitable algorithms will be selected for them.

So far the following main results have been obtained:

- A new algorithm for the solution of the magnetotelluric global optimisation inversion method by the Controlled Random Search (CRS) for the one-dimensional case was developed (Fig. 26) Several variants of the algorithm were tested - the use of the simplex and three-points approximation in combination with the global and local optimisation search.
- The optimisation inversion algorithm CRS was tested on the two-dimensional experimental data sets. The two-dimensional interpretation of the magnetotelluric data from the Minamikayabe polygon in Japan was presented and compared with other authors at the 14th Workshop on Electromagnetic Induction in the Earth', Sinaia, Romania, August 1998.
- A Czech computer program for the two-dimensional modelling of the geoelectrical structures with arbitrary anisotropy was tested with Japanese data sets and has been adapted for the interpretation of the magnetotelluric measurements in the see.
- Several new magnetotelluric sites were measured in West Bohemia. These experimental data will in future be used for comparison test experiments.
- The efficiency of different interpretation methods has been tested for a large set of the experimental data from Kakkonda (Honshu) which contains 75 stations arranged in 4 profiles. For all stations a one-dimensional interpretation was performed, the magnetotelluric directional characteristics were determined and, for all 4 profiles, the two-dimensional interpretation by the REBOCC inversion was performed (Fig. 27). The detailed comparison of the results for this data set will be performed and a three-dimensional model will be constructed.

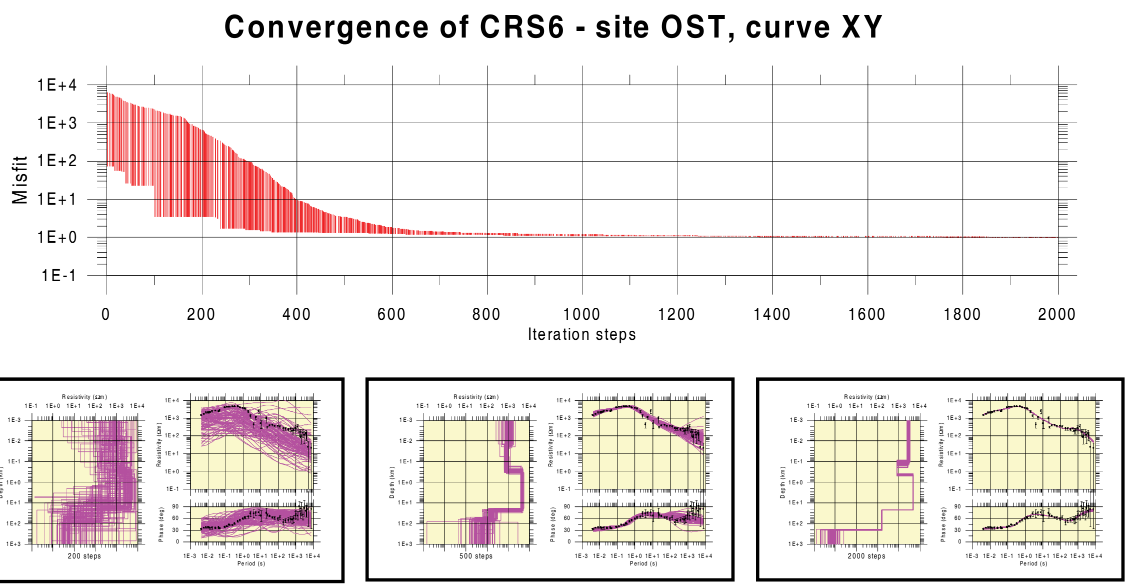

Fig. 26: Convergence of the CRS method for the MT station Ostrůvek and results after 200, 500, and 2000 iteration steps.

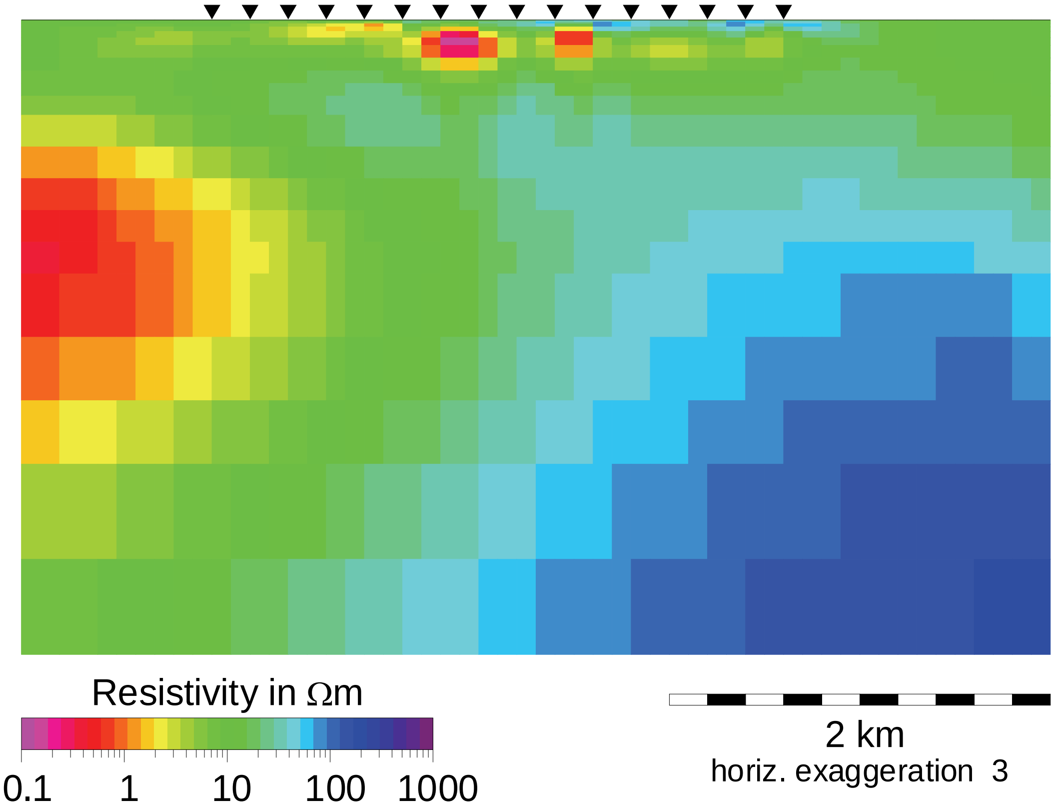

Fig. 27: 2-D geoelectrical section along a profile in Kakkonda, Japan.

Interpretation of the Cheb Basin Tectonic Evolution Based on the Sedimentological Analysis

(granted by GAASCR A3012705)

Duration: 1997 - 1999
Principal investigator: Lenka Špičáková
Co-wokers: D. Uličný, G. Koudelková

Tectonics is the main control on continental basin stratigraphy. Detailed patterns of subsidence in time and space give rise to characteristic geometry of the stratigraphic (depositional, sedimentary) units, separated by bounding unconformity or laterally correlative conformities at their tops and bases. The sedimentological analysis of basin fill makes it possible to define individual depositional units and the way in which they were stacked in time and space as a response to the tectonic activity. The proposed sedimentological research of the Cheb Basin, directed towards the analysis of tectonic processes in the past in relation to regional tectonic regime (correlation to general basin-fill characteristics of the Sokolov and North Bohemian Basins), will supplement and enrich the investigation of the area in question carried out by the Geophysical Institute of the Academy of Sciences of the Czech Republic and supported by the Grant Agency of the Czech Republic (seismological, geodetic, gravity and hydrogeological monitoring).

The project aims at the interpretation of the tectonic evolution (including the tectonic stress regime) of the Cheb Basin consisting in sedimentological investigation of the basin fill. Tectonic interpretation of the sedimentary infill of the Cheb Basin will be carried out in the context of the regional tectonic regime of the Eger Graben by comparison with both the Sokolov and North Bohemian Basins general basin-fill geometry, directions of sedimentary supply and stratigraphy.

Sedimentological investigation concentrated on the revision of all important outcrops. Five

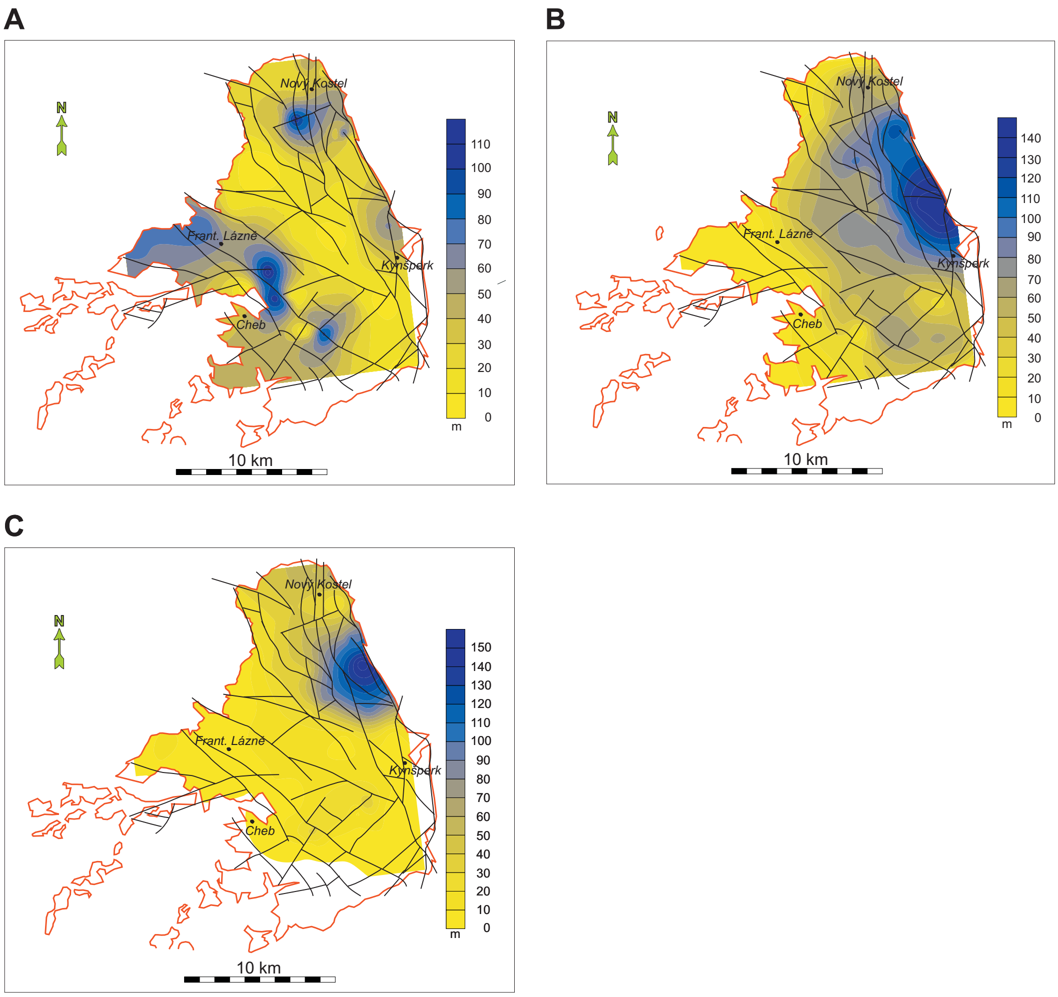

Fig. 28: Tectonic framework of the Cheb Basin and isopach maps of the main stratigraphic units.

localities enabled an application of the method of architectural analysis, the others were investigated by vertical profiles. Sedimentary environments of studied outcrops were established.

A revision of the boreholes was carried out and 91 of them were taken as a basis for isopach maps construction. Isopach maps were constructed for each of the main stratigraphic units (Fig. 28) Lower Clays and Sands Formation (1A), Main–Seam and Cypris Formation (1B), Upper Clays and Sands Formation (1C).

The tectonic framework was carried out on the basis of the digital model of the relief (DMR) and on the revision of the geological data (Fig. 28). It seems that the 'horse–tail' geometry of the fault zone controlled the geometry of the basin–fill. The hitherto results indicate that the sedimentary depo-centers change their positions in response to the tectonic stress regime changes. These findings will be made more precise by all basinal geological cross-sections as well as by the subsidence analysis, which will be undertaken during the next year.

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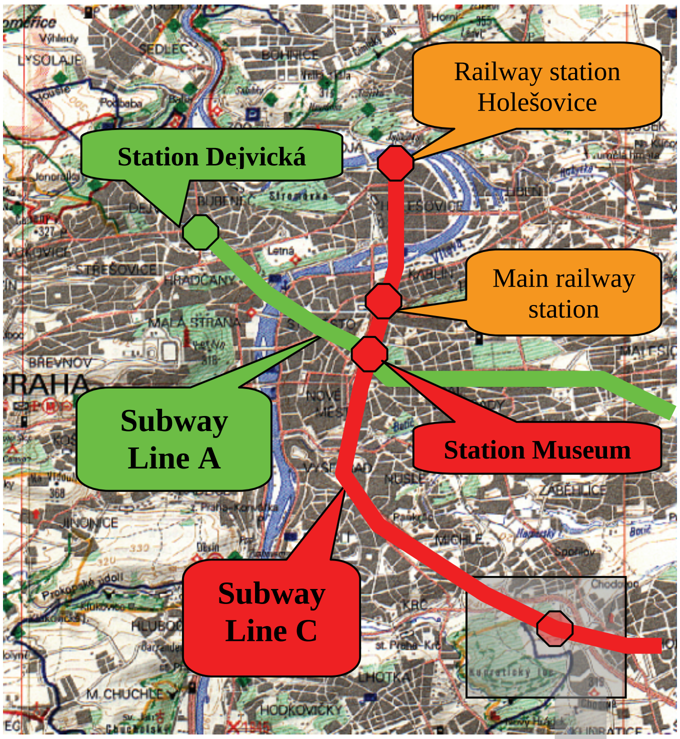

♦ When arriving by plane …

Take bus No.119 to the bus terminal Dejvická. Take Subway Line A (green color) to station Museum. Change to line C (red color), direction Háje. Get off at station Roztyly. You can see the building of the institute behind the highway. You can recognize it by the great white parabolic antenna with the label NEXTEL.

♦ When arriving by train…

Most probably you will arrive at the Main railway station or railway station Holešovice. Take Subway, Line C, direction Háje. Go until station Roztyly. When you get to the surface, you can see the building of the institute behind the highway. You can recognize it by the great white parabolic antenna with the label NEXTEL. The final walk will take about 10 minutes.

♦ When arriving by car …

If you go from Prague centre south in direction Brno, take Exit Spořilov and immediately another Exit Spořilov. Coming from Brno, take Exit Spořilov. Follow black lines in the bottom map.