Academy of Sciences of the Czech Republic

Institute of Geophysics

Report 2006–2007

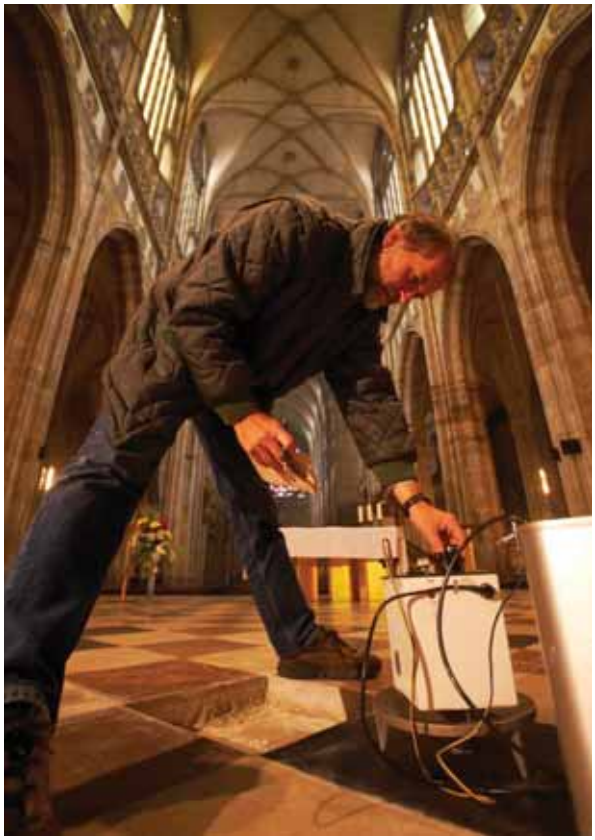
Contents

Institute of Geophysics of the Academy of Sciences of the Czech Republic

The Institute of Geophysics of the Academy of Sciences of the Czech Republic is a public research institution. The mission of the Institute is to conduct fundamental research in physics of the solid Earth and its immediate space environment, in order to increase the level of general scientific knowledge as well as to contribute to practical application of the results of scientific research. Geophysical interpretations include studies of the lithosphere and sub-lithosphere structure, crustal studies, geodynamics of the seismoactive regions, climatic changes, solar-terrestrial relations, environmental geomagnetism and many others. Theoretical modelling and numerical simulations of geophysical fields are integral parts of the research programme of the Institute. The activities of the Institute comprise regular observatory monitoring of Earth's physical fields as well as a broad collaboration with world-wide network services and data centers. The research staff of the Institute of Geophysics consists of approximately 60 university-educated personnel organized in five research departments: seismology, geothermics, geomagnetism, geoelectricity, and tectonics and geodynamics. The research activities are supported by about 10 technicians at the research departments and 30 staff members of operating division (IT center, library, administrative and technical services). Because a significant part of the mission of a research institution is exchange and dissemination of knowledge, the Institute organizes scientific meetings and seminars at both national and international levels, and publishes a scientific journal Studia Geophysica et Geodaetica. In collaboration with universities the Institute of Geophysics takes part in higher education and in university research programmes, especially at the doctoral level.

A direct successor to the State Institute of Geophysics founded in 1920, the Institute of Geophysics was incorporated into the Czechoslovak Academy of Sciences in 1953. Currently it is one of 57 public scientific institutes of the Academy. (Detailed information about the structure of the Academy of Sciences of the Czech Republic and other institutes can be found at www.cas.cz/en/).

In 2006 and part of 2007, the Institute's director was RNDr. Aleš Špičák, CSc. In 2007, according to changes in the legal and infrastructural status of all institutes of the Academy, the Institute of Geophysics became a Public Research Institution with a new Institute's Board and Supervisory Board. RNDr. Pavel Hejda, CSc. was elected and appointed as director of the Institute in spring 2007.



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The Lisbon earthquake (1755), rough woodcut – broadsheet illustration, edited by J. Kamenický, Litomyšl (Bohemia), erroneously dated as 1750. Original in the Scientific Library, Plzeň. Copy: http://nisee.berkeley.edu/kozak

Research departments

Department of Geoelectricity

Head: RNDr. Josef Pek, CSc.

- investigations of the crustal and upper mantle electrical conductivity
- theoretical and methodological research of electromagnetic fields and their numerical modelling
- research of external geoelectro-magnetic fields
- investigations of the solar-terrestrial relations

Department of Geomagnetism

Head: RNDr. Eduard Petrovský, CSc.

- observations of the Earth's magnetic field
- field measurements of secular variations
- geodynamo modelling
- space weather studies
- effect of solar and geomagnetic activites on climatic changes
- rock and environmental magnetism

Department of Geothermics

Head: RNDr. Jan Šafanda, CSc.

- experimental and theoretical investigations of the temperature field of the Earth's crust and upper mantle, temperature logging in boreholes
- experimental studies of the thermophysical properties of crustal rocks, thermal conductivity and diffusivity and radiogenic heat production
- instruments for geothermal research, portable thermometers for borehole logging and systems for a long-term temperature monitoring
- reconstruction of climatic changes from temperature-depth profiles in deep boreholes
- research into the air, ground and bedrock temperature coupling and into the thermal regime within the soil and the underlying bedrock

Department of Seismology

Head: RNDr. Jan Šílený, CSc.

- operating a regional network of broadband seismological stations
- monitoring and interpreting the local seismicity in West Bohemia
- study of deep geological structures down to the mantle litosphere
- theoretical research on seismic waves generation and propagation in complex structures
- study of the Earth's crust by using active seismic experiments

Department of Tectonics and Geodynamics

Head: RNDr. Aleš Špičák, CSc.

- processes at convergent plate margins, focused on tectonic interpretation of earthquake distribution and mechanisms
- orogenic processes and rheology of Earth's crust and mantle in ancient orogens
- processes of magma ascent and diapirism studied by analogue modelling and in the field
- evolution of sedimentary basin fills as sensitive records of the interaction between tectonic processes, sea-level fluctuations and climate changes
- recent crustal movements in tectonically active regions studied using gravity and geodetic methods
- Earth tides monitoring and analysis, slope stability monitoring based on tilmeter and groundwater observations
- studies of oriented microporosity of rocks and its relation to elastic properties and permeability, e.g. for planning of radioactive waste repositories
- microgravity measurements in engineering geology and archeology

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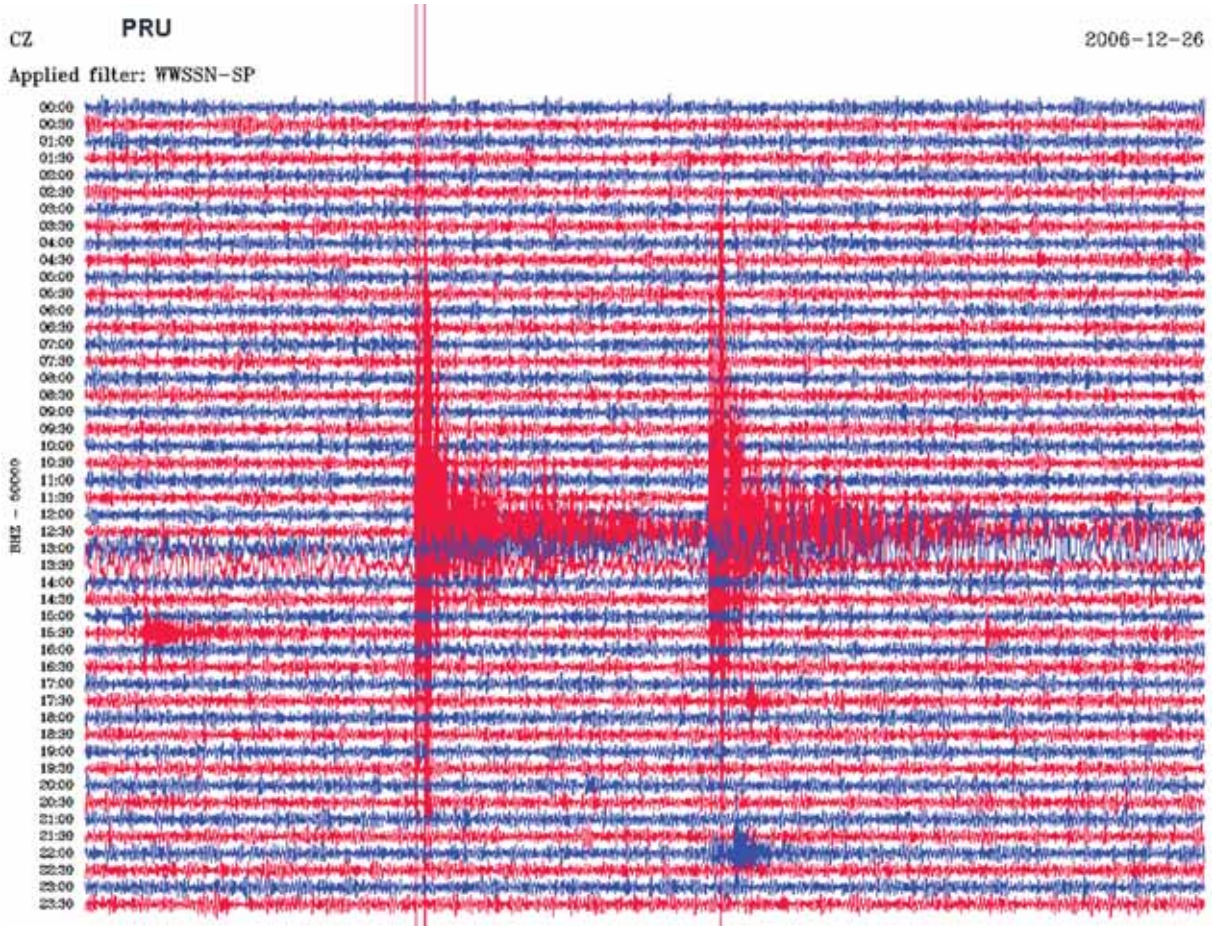


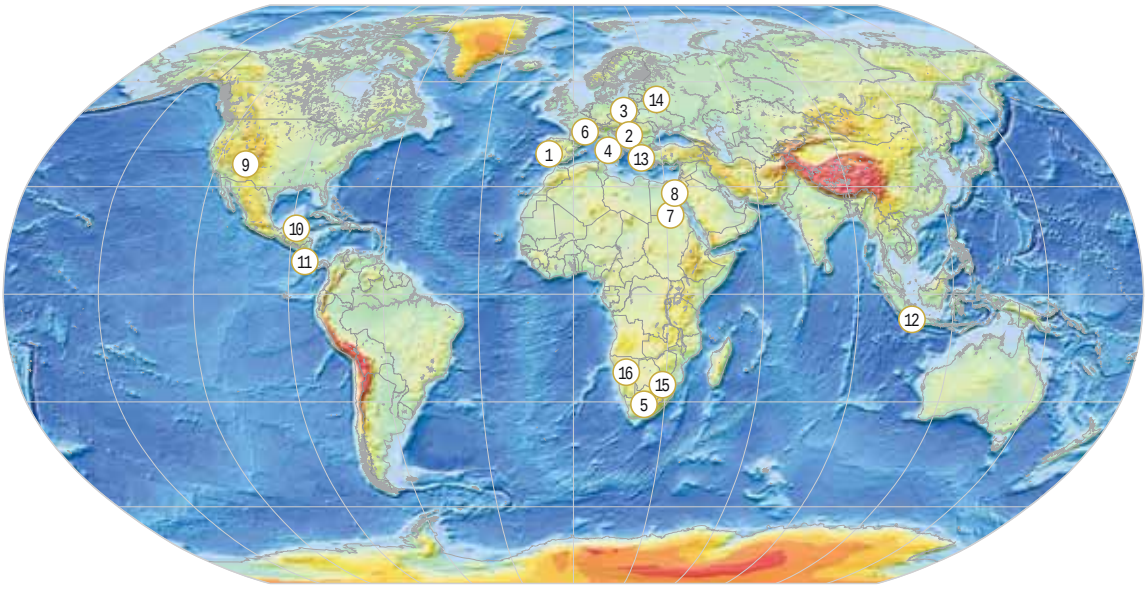
Seismogram from seismic station Pruhonice (PRU), of December 26, 2006. The record shows twin earthquakes of magnitudes 7.1 and 6.9 that occurred in Taiwan, separated by an 8-minute pause.

Main research topics

The core of the yearbook is devoted to short communications summarizing the principal results achieved in various lines of research at the Institute during the years 2006 and 2007.

Because the range of topics studied and methods applied is very broad, the organization of the text does not strictly follow the administrative structure of the Institute's departments. Instead the topics are arranged in several groups, following a direction from continental- and regional – scale studies of geodynamics, lithosphere structure and tectonics, through more focused studies of rock properties, seismicity, and geophysical characterization of environmental change, to theoretical studies and research on the outer Earth and Solar System processes.

The global focus of research undertaken at the Institute of Geophysics is illustrated by the map below:



| 1 Geothermal climate change observatories in Portugal
| 2 Geothermal climate change observatories in Slovenia
| 3 Deep electromagnetic soundings across the Teisseyre-Tornquist Zone in Pomerania, NW Poland
| 4 Passive seimological experiment in Italy
| 5 Study of petrological properties and rheology of upper mantle eclogite
| 6 Paris - world calibration campaigns of relative and absolute gravity meters
| 7 Gravity measurements in Aswan
| 8 Gulf of Suez - gravity and GPS investigation of onshore faults geodynamic activity
| 9 Structural and sea-level history of the Cretaceous Western Interior
| 10 Geothermal research of the impact structure Chicxulub
| 11 Geodynamics of the Middle America region
| 12 Geodynamics of the Indonesia region
| 13 Structural and geodynamics research in the Gulf of Corinth region using gravimetry
| 14 Geothermal evidence of recent decay of permafrost
| 15 Investigation of rockbursts in DRIEFONTEIN mines
| 16 The Kaoko Belt, NW Namibia; field research of tectonic controls of repeated magmatic activity during formation of orogenic belts

Deep structure, seismotectonics and tectonic evolution at convergent plate margins

Subduction of lithospheric plates at convergent plate margins generates the world's largest and most destructive earthquakes, tsunamis, volcanic eruptions and igneous provinces; simultaneously, regions above subduction zones host much of the world's population. Intensive investigation of convergent plate margins thus belongs to priorities in geosciences all over the world. Our studies of this exciting phenomenon benefit from widely accesible sets of global seismological data - hypocentral determinations 1964-2005 of International Seismological Centre relocated by Engdahl et al. (1998) and fault plane solutions 1976-present of Harvard seismological group (HCMTS).

In SE Asia, the spatial analysis of earthquake foci distribution has been correlated with sea floor morphology and available results of GPS measurements (Špičák et al., 2007a). The analysis revealed the existence of a distinct strip of earthquakes distributed along the Java trench, separated by a trench-parallel, 50-150 km wide aseismic link from seismicity belonging to the Wadati-Benioff zone of the recently subducting slab. We interpret the distinct along-trench seismicity as a consequence of an onset of a new subduction cycle due to the rapid convergent movement of the Indo-Australian plate relative to the aseismic lithospheric link.

In Central America, we have attempted to study the internal tectonic structure of the subducting Cocos plate analysing aftershock sequences that occurred in the respective Wadati-Benioff zone (Špičák et al., 2007b). We concluded that (i) earthquakes of each aftershock sequence are distributed in a narrow plane-like body; parameters of such a plane (azimuth, dip) were found for each sequence; (ii) planes controlling the distribution of hypocentres of aftershock sequences are probably inherited planes of weakness that originated during the development of the lithosphere of the Cocos plate and are recently activated by the process of subduction; (iii) fault planes along which the seismic slip of individual earthquakes of the aftershock sequences was observed probably originated in the process of Cocos plate bending and subduction.

Figure 1

Tengger Caldera with the Bromo volcano and Simeru volcano in the background are related to the subducting slab, the Wadati- Benioff zone of which does not correlate well with the position of Java trench.

I.G. research staff involved:

Aleš Špičák, Václav Hanuš, Jiří Vaněk, Marie Běhounková

References:

Špičák A., Hanuš V. and Vaněk J., 2007a. Earthquake occurrence along the Java trench in front of the onset of the Wadati-Benioff zone: beginning of a new subduction cycle? *Tectonics, 26, TC1005, doi:10.1029/2005TC001867.*

Špičák A., Hanuš V., Vaněk J., and Běhounková, M., 2007b. Internal tectonic structure of the Central American Wadati-Benioff zone based on analysis of aftershock sequences. *JGR, 112, B09304, doi:10.1029/2006JB004318*

European mantle lithosphere

Lithosphere thickness has been modelled from static terms of relative P residuals evaluated from data of dense networks of temporary and permanent stations in several European regions ranging from the Variscan belt to the Baltic Shield (Fig. 1, Babuška and Plomerová, 2006; Plomerová et al., 2008). We also model three-dimensional fabrics of the mantle lithosphere by joint inversion and interpretation of shear-wave splitting parameters (fast S polarization and time delay of the slow shear wave) and P residual spheres, showing directionally dependent terms of relative residuals (Vecsey et al., 2008; Kozlovskaya et al., 2007). Changes in orientation of the large-scale anisotropy, caused by systematic preferred orientation of olivine, identify boundaries of domains of mantle lithosphere (Babuška and Plomerová, 2006; Plomerová et al., 2006; Plomerová et al., 2007). Depending on symmetry and orientation of fabrics of the lithosphere domains, lateral changes are reflected in either P-velocity anisotropy and/or shear-wave polarizations (Babuška et al., 2008). Individual domains are characterized by a consistent large-scale orientation of anisotropy approximated by hexagonal or orthorhombic symmetry with generally inclined symmetry axes. The domains are separated by mapped tectonic boundaries (sutures), which cut the entire lithosphere, but often with an offset relative to surface traces of their crustal parts (Babuška et al., 2007). Our findings support a plate-tectonic view of the continental lithosphere as a mosaic of rigid blocks of the mantle lithosphere with complicated but relatively sharp contact zones (Babuška and Plomerová, 2006; Plomerová et al., 2008; Vecsey et al., 2007). These contacts are blurred by the easily deformed overlying crust terranes.

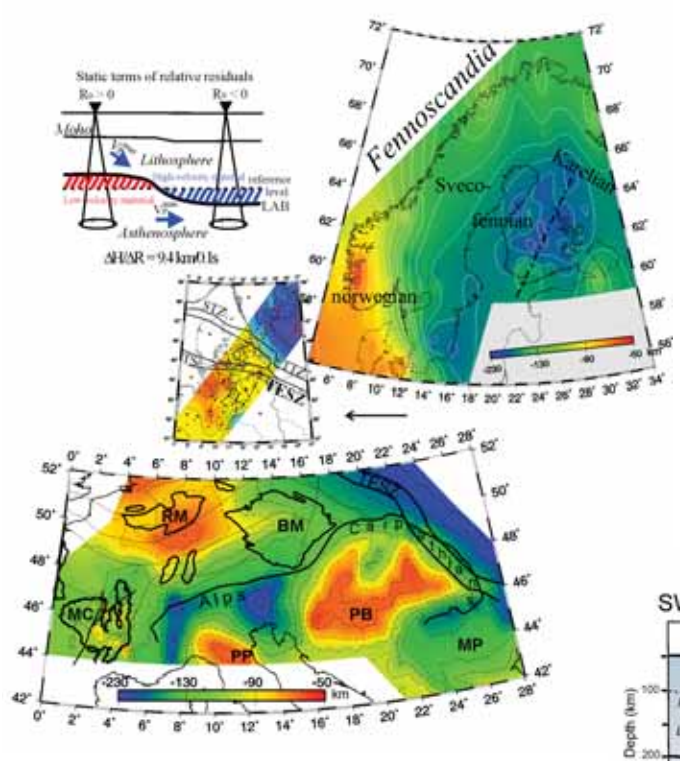


Figure 1

Models of the lithosphere thickness in central (Babuška and Plomerová, 2006) and northern Europe (Plomerová et al., 2008) bridged across the NW end of the Trans-European Suture Zone (TESZ). The models are compiled from data collected in our regional studies. The lithosphere thickens in the Precambrian part of Europe, NE of the TESZ. Mountain roots of the Western and Eastern Alps, and the southern Carpathians, as well as lithosphere thinning in the Pannonian Basin (PB), Rhenish Massif (RM), Po Plain (PP), volcanic centres in the French Massif Central (MC), and the Eger Rift in the Bohemian Massif (BM) are distinct in the Phanerozoic part of Europe, SW of the TESZ.

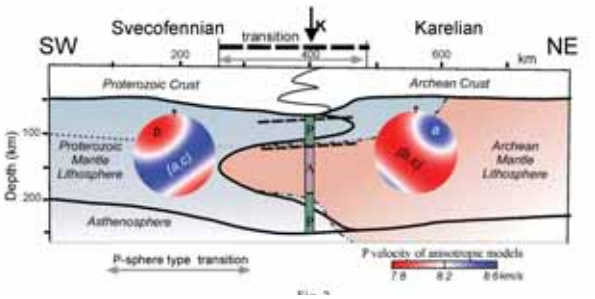


Figure 2

Model of the mantle lithosphere along the SW-NE profile (dot-dashed line in Fig. 1) across the Proterozoic and Archean parts of the central Fennoscandia. Anisotropic structure of the mantle lithosphere is approximated by hexagonal aggregates with the high-velocity a axis dipping in the NE azimuth (in the Archean), or with the high-velocity (a,c) foliation plane dipping to the SE (in the Proterozoic) and shown in velocity distributions presented in polar projections of the lower

hemisphere. The velocity distribution results from the joint inversion of body-wave anisotropic parameters. The alternating layers of the Archean (A, violet) and Proterozoic (P, green) ages of mantle xenoliths support the model derived from seismic anisotropy. For detailed explanation see Plomerová et al. (2006) and Vecsey et al. (2007).

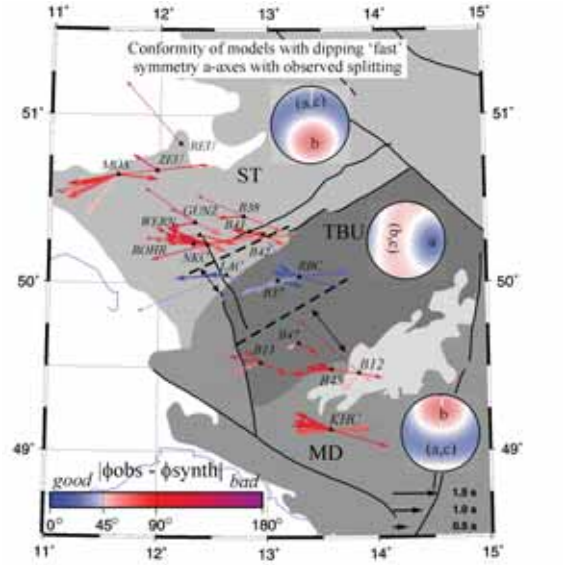


Figure 3

Anisotropic models of three domains of the mantle lithosphere in the western Bohemian Massif and conformity of the observed and synthetic splittings calculated for aggregates retrieved from inversions of P spheres. Results of the two independent data sets suggest two different 3D anisotropic models: one with hexagonal 'slow' symmetry axis b and divergently dipping (a,c) foliations (Saxothuringian – ST and Moldanubian - MD) and the other with hexagonal or orthorhombic symmetry with dipping high-velocity lineation a (Teplá-Barrandian -TBU). The orientations of the hexagonal b-axis model explain well directional variations of the splitting within the ST and MD, while this symmetry fails to explain the splitting at stations located above the TBU mantle lithosphere. On the other hand, the hexagonal a-axis model explains much better the polarizations at the three TBU stations, while it fails to model the observations at stations in the ST and MD. Our study emphasizes the importance of combining different methods of analysis and using complementary datasets in the three-dimensional analysis of mantle fabrics. The dashed lines approximate the TBU mantle domain boundaries, which are north-westerly shifted (dashed double arrows) relative to the crustal boundaries of the unit and indicate and underthrusting of the MD mantle lithosphere beneath the south-eastern rim of the TBU (Babuška et al., 2007).

I.G. research staff involved

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References

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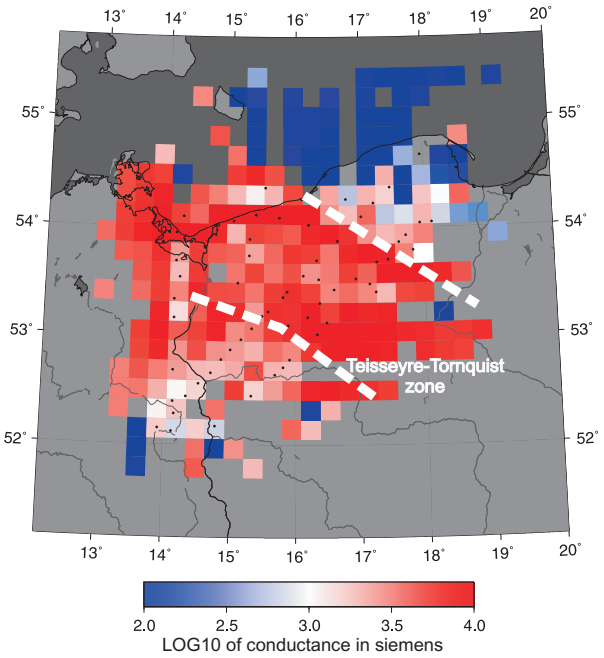
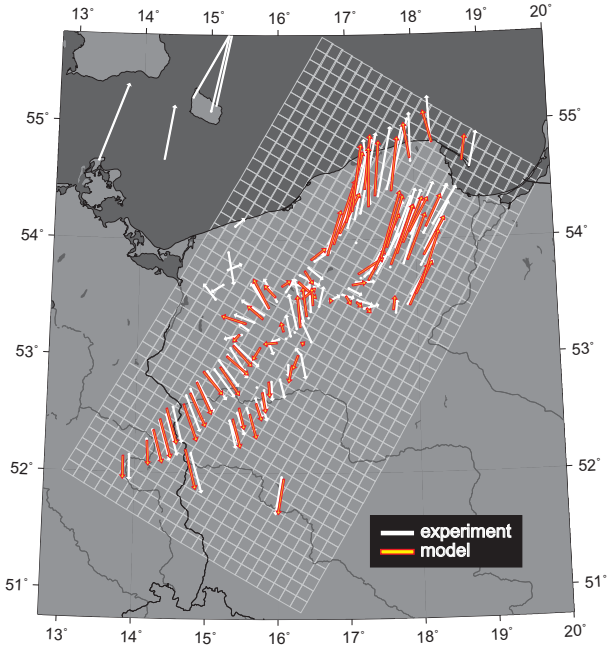
Vecsey, L., Plomerová, J., Babuška, V., 2008. Shear-wave splitting measurements – problems and solutions. *Tectonophysics, in press.*

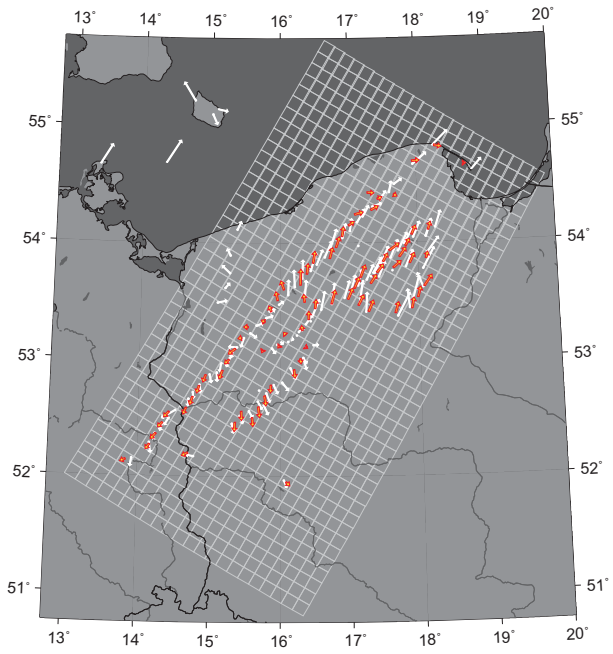
EMTESZ/CEMES: Crustal and subcrustal electrical model of the Transeuropean Suture Zone

The Trans-European Suture Zone (TESZ) is the most prominent geological boundary in Europe, crossing NW-SE through the continent and exceeding 2000 km in length. The magnetotelluric experiment called EMTESZ (ElectroMagnetic probing of the TransEuropean Suture Zone), has been carried out since 2001 in Pomerania, NW Poland, as a multinational collaboration project aimed at constructing, by means of broadband passive electromagnetic soundings, the electrical image of the entire lithosphere along a traverse running from the Polish Basin to the East European Craton and crossing the TESZ close to previously conducted Polonaise seismic soundings. Within the experimental phase of the project, more than 100 broadband and long period magnetotelluric sites have been set up, from which 25 broadband soundings across the margins of the Teisseyre-Tornquist zone have been provided by the Czech team. The field measurements have been supplemented with long period observatory data of the CEMES project targeting at disclosing deep conductivity inhomogeneities in the upper mantle beneath the TESZ. Within a broader complex of interpretation techniques, we have developed an algorithm for a quasi-3 -D thin sheet inversion of the geomagnetic induction parameters by the stochastic Markov chain Monte Carlo method. The approach simulates samples from the probability distribution of the integrated conductivity across the area of interest, providing thus extended quantitative information on both the conductance means and their uncertainties. The inferred conductance models confirm an essentially two-dimensional, high conductivity character of the TESZ, with





a stable strike of approximately N60°W, and high resistivities on the East European Craton and moderately increased resistivity on the Paleozoic platform. The models further support the qualitative idea of the TESZ being separated into three distinctly different units in this region: a resistive zone in the center and two conductive ones on the margins. The dimensionality of the subsurface structures is not completely uniform, indicating several distinct anomalies and/or three-dimensional structures.



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Publications:

S. Kováčiková, V. Červ and O. Praus :2005, Modelling of the conductance distribution at the eastern margin of the European Hercynides, *Studia geoph. et geod. V. 49/3, 403-421.*

H. Brasse, V. Červ, T. Ernst, W. Jozwiak, L.B. Pedersen, Iv. M. Varentsov and EMTESZ-Pomerania Working Group: Probing the electrical conductivity structure of the Trans-European Suture Zone, *EOS, Vol. 87, No. 29, 18 July 2006.*

V. Červ , M. Menvielle and J. Pek: Stochastic Interpretation of Magnetotelluric Data, Comparison of Methods, *Annals of Geophysics, Vol. 50, N.1, 7-19.*

Figure 1

Left - Model of average conductances obtained by the MCMC inversion of long period induction arrows and horizontal inter-station geomagnetic transfer functions across the TESZ in Pomerania, NW Poland. Only cells with 90% of the Markov chain conductance values concentrated within one third of a decade are shown. Middle and right - Fit of the model and experimental induction arrows, real and imaginary, respectively, along two basic profiles across the TESZ for the period of 1024 s.

Distribution of seismic activity in the western part of the Bohemian Massif and the possibility of its tidal triggering

An uninterrupted sequence of local seismic observations in the earthquake swarm area of West-Bohemia/Vogtland is available since 1991 thanks to the operation of the Czech seismic networks Krasnet and WEBNET. We have extended this data set (Babuška et al., 2007) by the arrival time measurements from the seismic stations operating on the German territory to obtain an integral image of the lateral and depth distribution of seismic activity in the whole seismoactive area. We have relocated the earthquakes with the aim of having an improved control of hypocentral depth to verify the previous results indicating the increase of the depth to the north and west. Before locating all the events we have refined the 1-D velocity model to include the effect of newly introduced seismic stations from the northern part of the area. Fig. 1 shows the resulting distribution of hypocenters. The depth location error was less than ±0.65 km in the central part and less than ±2.0 km in the periphery of the area. The final locations, shown in Fig. 1, confirmed the deepening of earthquake foci to the northwest. The maximum depths of foci change from less than 12 km in the central Nový Kostel area to depths of 20 km on a half way to Plauen (see Fig. 1, profile A-B), which represents a difference well above the maximum depth location error.

Figure 1 indicates that the overwhelming majority of earthquakes occurs in the Nový Kostel area. Taking only ML>1.0 earthquakes for which the data set is assumed to be complete, one gets 1052 earthquakes in the NK area, which amounts to 87% of all recorded events. The NK area dominates also in terms of the released seismic moment M_o with 86% of the total seismic moment (1.4×10^{16} Nm) released between 1991 and 2004.

The possibility of tidal triggering of the earthquake swarms was tested in the study of Fisch-

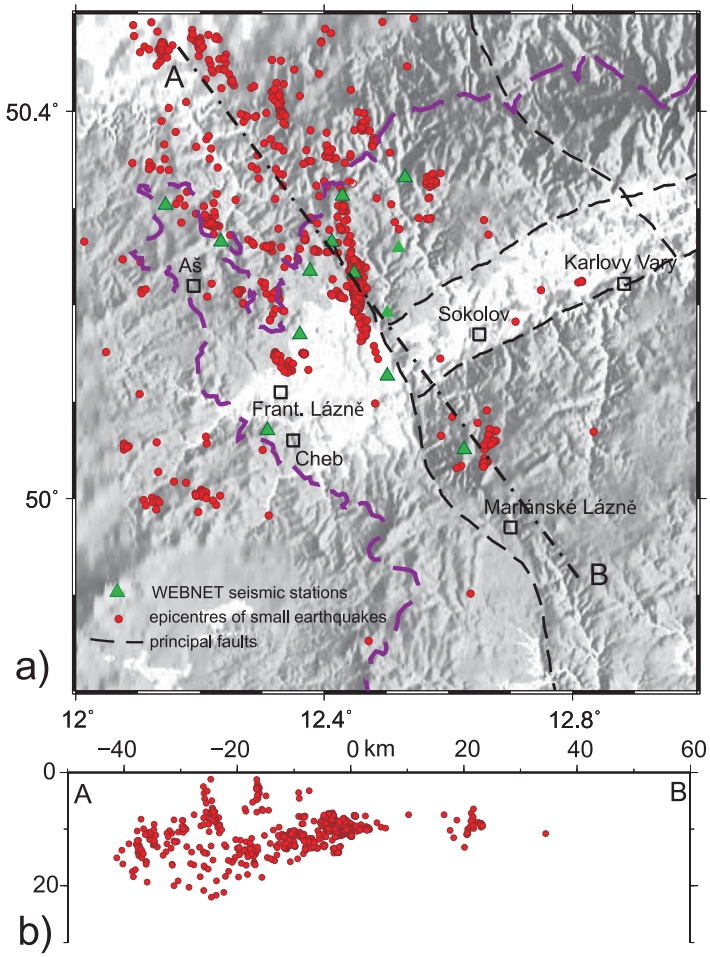

Figure 1.
Distribution of hypocenters in the West-Bohemia/Vogtland area in the period 1991-2004. Map of epicenters (a) shows 6262 events in the range of ML magnitudes from -1 to 3.2. The depth cross-section (b) projects hypocenters in a band 20 km wide along the profile AB.

er et al. (2006). We examined tidal triggering as influence of tidal stresses to launching the swarm activity in relative absence of other stress disturbances. The onset times of 46 swarms of mostly ML<3 earthquakes that occurred in the period 1991–2005 displayed an increased occurrence near the fortnightly maximum of tidal extensive normal stress (see Fig. 2). The statistical test however did not prove a statistically significant correlation indicating a triggering effect of fault extension due to tidal loading. We also examined tidal effects to the already running seismic activity of the prominent 2000 swarm by comparing the tidal stress distribution in the investigated period with the distribution of tidal stresses in the occurrence times of each earthquake. The results show that these distributions are similar, which indicates that individual earthquakes occur independently of tidal stresses. The unclear tidal correlation of the swarm seismicity may be interpreted by small amplitudes and rates of tidal stress changes compared to the amplitudes and rates of coseismic stress perturbations and of pressure bursts of deep generated fluids.

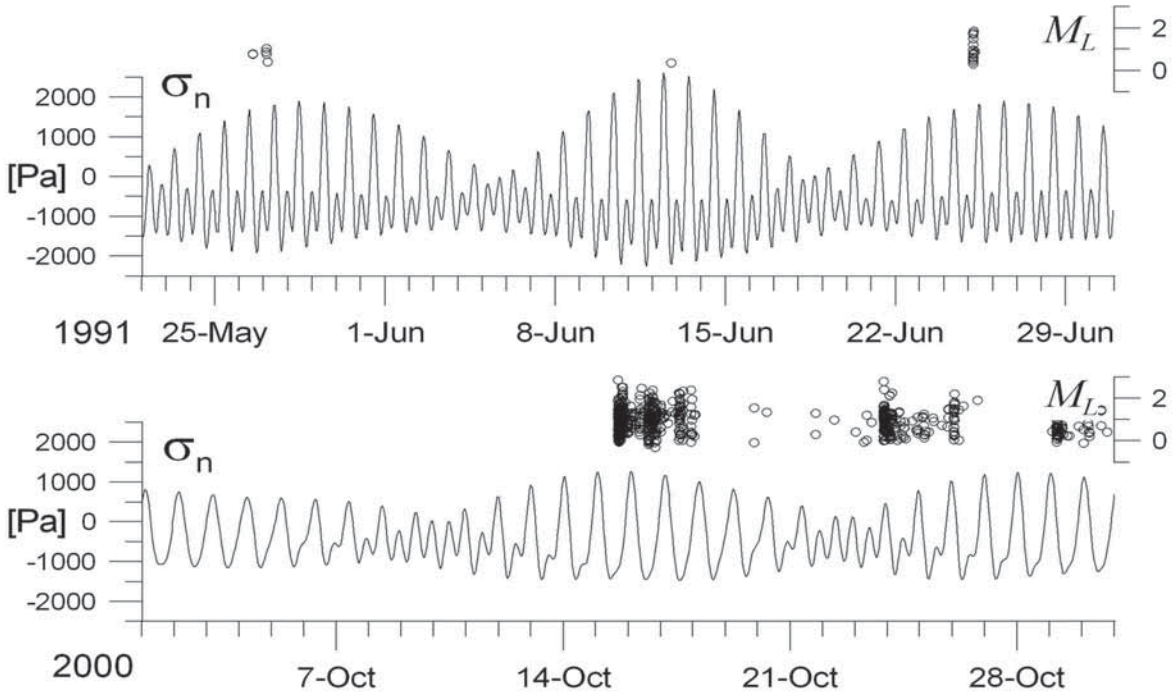

Figure 2

Time occurrence of the swarm activity (open circles) is shown for the swarms of 1991 (top) and 2000 (bottom) in comparison with the course of the tidal normal stress.

I.G. research staff involved:

Tomáš Fischer, Lumír Skalský, Vladimír Babuška, Jaroslava Plomerová, J. Horálek, WEBNET network staff.

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Fischer T., Kalenda P., Skalský L., 2006. Weak tidal correlation of NW-Bohemia/Vogtland earthquake swarms*, Tectonophysics, 424, 259-269.*

Gravity and magnetic investigation of an implemented Quaternary volcanic structure in West Bohemia

After investigation of a tuff-tephra deposit near Mýtina (West Bohemia) it was not clear if the pyroclastic deposits were erupted from an initial maar beneath the Železna hůrka Quaternary scoria cone. It has been suggested that the volcanic vent might coincide with a morphological depression (diameter ca. 500 m, depth ca. 50 m) northwest of Železna hůrka. To answer this question we started geophysical surveys in order to check if the morphological depression exhibits any anomalous features. Gravity and magnetic measurements were selected as the most suitable techniques, and applied within a north-south oriented strip of about 1200 m length and 200 m width. Both geophysical datasets revealed significant anomalies. The gravity map shows a distinct gravity low of about 2.5 mGal in the centre of the morphological depression. The magnetic map exhibits a positive anomaly up to 300 nT, most likely related to identical source as the gravity anomaly. As there is no specific feature present in the geological map of the area, we propose a volcanic structure (maar-diatreme), filled by volcanic material and covered by alluvium, and possibly also by maar sediments, as a source of geophysical anomalies. Tentative 3D gravity model fits the observed data, based on low density of such volcanic vent fill material and sediments.

The results of geophysical, as well as geochronological and petrochemical investigation, support our idea that near Mýtina a Quaternary maar is present, as part of a more complex volcanic system comparable to the Meerfeld-Mosberg volcanic system in the Westeifel/Germany, rather than just the single little scoria cone of the Železná hůrka itself. The Mýtina maar would be the first Quaternary maar in Central Europe located east of the classical Eifel maar district in Germany and north of the Alps. This is significant for geodynamic investigations of seismotectonic activity in West Bohemia.

I.G. researchstaff involved:

Jan Mrlina, Michal Seidl, Václav Polák

Reference:

Mrlina, J., Kämpf, H., Geissler, W.H., and van den Bogaard, P. (2007): Assumed Quaternary maar structure at the Czech/German border between Mýtina and Neualbenreuth (western Eger Rift, Central Europe): geophysical, petrochemical and geochronological indications. *- Z. geol. Wiss., Berlin, 35, 4–5, 213–230*

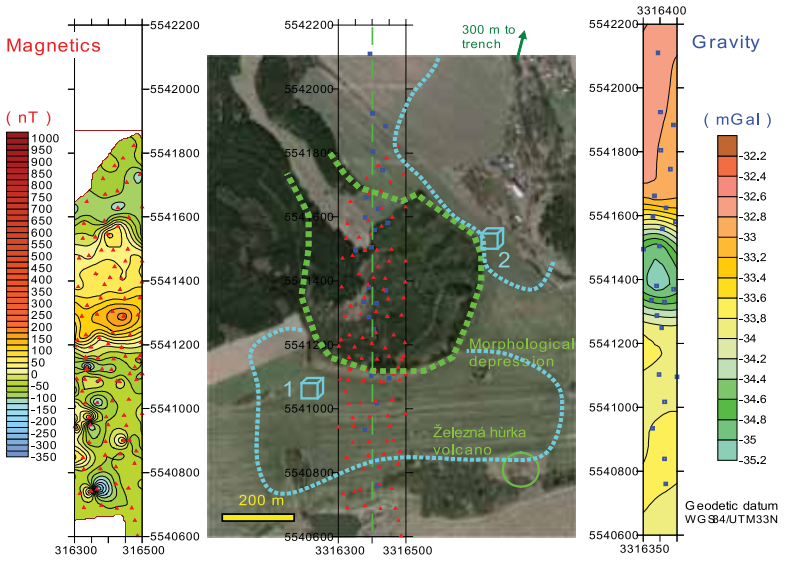

Figure 1

Magnetic and gravity maps with observation points location on an aerial photograph. Position of anomalies is clear in relation to the morphological depression covered by forest in the central part of the area. Sampling locations 1 and 2 (blue cubes) correspond to tephra (volcanic bombs). Approximate extent of tephra cover, based on aerial photographs and field reconnaissance, is marked by blue lines.

Oriented microporosity and its relation to elastic properties and permeability

Every rock contains some amount of pores or open cracks, which strongly influences petrophysical properties of rocks. Unlike meso- or macroscopic brittle structures, the direct analysis of such small-size discontinuities is difficult because it requires a 3D geometric description at microscale. However, some specific physical features of rocks are closely linked to pores. The aim of our research is to establish the relationship between the pore space geometry, permeability anisotropy, microstructure and mesostructure of several rock types. As a first step in our research, the origin and spatial orientation of microporosity in two eclogites with different microstructures were studied by 1) quantitative and qualitative microstructural analysis of grains and grain boundaries, 2) measurement of lattice preferred orientation (SEM-EBSD) and 3) experimental measurement of velocity of elastic P-waves in spherical samples. Results show good correlation between the elastic properties and the orientation of grain boundaries and cleavage planes in clinopyroxene (Machek et. al., 2007). The magnitude and anisotropy of velocity change with confining pressure shows that microporosity in the fine-grained sample is relatively large and strongly preferentially oriented, whereas it is significantly lower and less preferentially oriented in the coarse-grained sample. From velocity changes we can deduce that the grain size of the rock forming minerals controls the amount of microporosity. Also, the orientation of microporosity depends mostly on preferred orientation of grain boundaries and somewhat less on the orientation of cleavage planes. Grain boundaries are therefore the most important contributors to the bulk microporosity in the studied rocks.

I.G. research staff involved:

M. Machek, P. Špaček, S. Ulrich

References:

Machek, M., Špaček, P., Ulrich, S. and Heidelbach, F., 2007. Origin and orientation of microporosity in eclogites of different microstructure studied by ultrasound and microfabric analysis. *Engineering Geology, 89,3-4, 266-277*

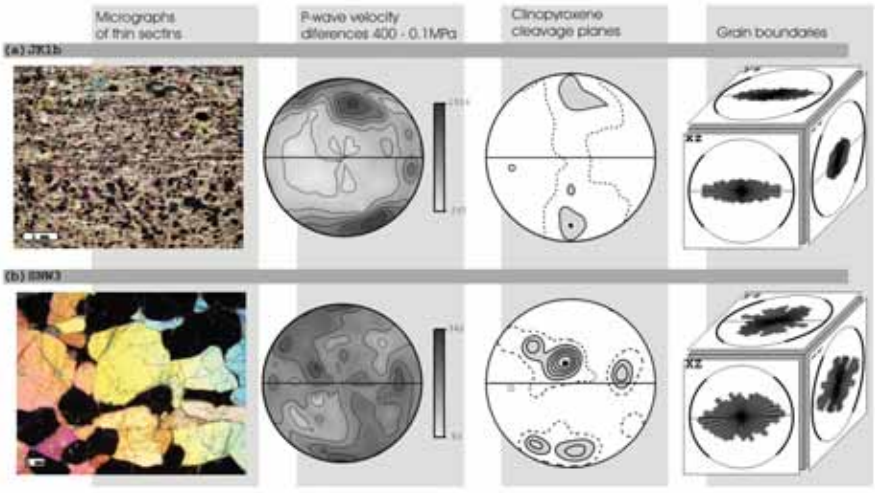

Figure 1

Photomicrographs of eclogite samples and relation between results obtained by 3 independent methods used to characterize the microstructure. Stereodiagrams of P-wave velocity differences are showing preferred orientation of microporosity. Cleavage planes and grain boundaries are microstructural planar features along which open space is most likely present in eclogites. (a) fine-grained eclogite and (b) coarse-grained eclogite.

Assessing rates of subsidence, sediment supply and eustatic sea-level change in a transtensional basin fill using sequence stratigraphy

Basin fills record complex interactions between tectonic subsidence, eustasy, sediment supply, basin margin physiography, and compaction. In spite of the optimism of early sequence stratigraphic models, interpreting the above controlling parameters from the sedimentary record remains a challenge. An analysis of stratigraphic architecture in three dimensions, utilizing both subsurface and outcrop data, with time control and a comparison to independent data on extrabasinal controls, can, however, significantly narrow the range of possible scenarios. The Bohemian Cretaceous Basin combines features of a shallow-water (mostly <100 m) epicontinental seaway formed during a global transgression with those of a tectonically active, transtensional setting. The basin formed under greenhouse climate and was affected by strong axial currents. Dense well-log coverage combined with locally high-quality exposures and biostratigraphic control make it possible to examine in detail the interplay of parameters that controlled the basin filling.

Sand-dominated deltas formed sequences at several spatial scales that reflect nested transgressive-regressive cycles with durations ranging from tens of kyr to millions of years. Progradation directions and distances, thicknesses and internal geometry of the individual sequences were controlled primarily by intrabasinal faulting, basin-scale changes in subsidence rate, eustatic fluctuations and localized bathymetric changes due to successive filling of the basin. Along-strike change in sediment input from different parts of the source area and a short-lived uplift of a secondary clastic source provided additional controls on the sequence geometry. Long-term stacking

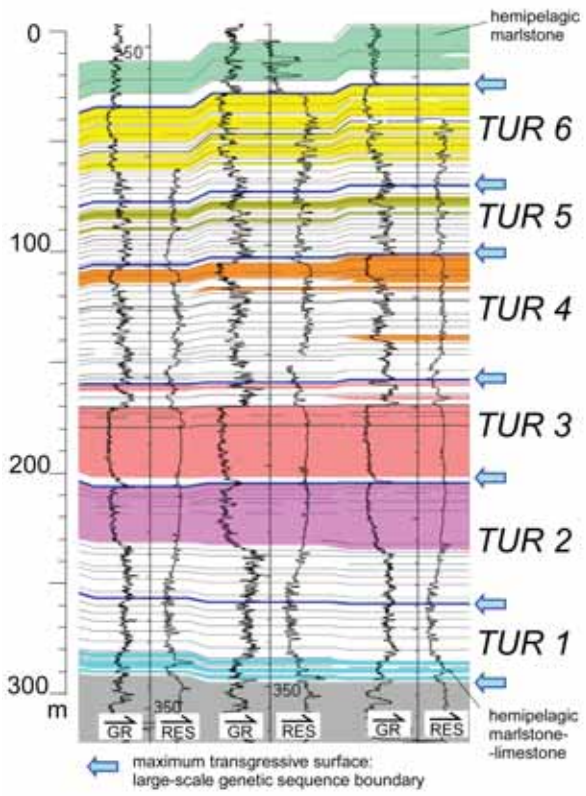

Figure 1

Example of high-resolution correlation of gamma-ray (GR) and resistivity (RES) well logs of Turonian-age genetic sequences in the Bohemian Cretaceous Basin. Each correlation line in the diagram is an interpreted transgressive surface (surface formed during increase in water depth caused by relative sea-level rise). The large-scale sequences TUR 1-6 represent stacks of prograding deltaic and/or shoreface clastic wedges, separated by major transgressive surfaces. Colour infills in indicate sandstone bodies, except blue and green tones representing fine-grained hemipelagic rocks. Unfilled space in the diagram represents fine-grained offhore clastics.

patterns as well as rough estimates of decompacted thickness vs. sequence duration suggest that long-term accommodation rates were low (<80m. Ma^{-1}) during the Early to Middle Turonian, with minor intrabasinal faulting, but became successively accelerated in the Late Turonian and Early Coniacian, up to 200-300 $m.Ma^{-1}$. A significant part of this acceleration was caused by increased subsidence rate accompanied by structural partitioning of the depocentre and partly compensated by increased sediment input rates. This event probably reflected an increase in regional strain rate in Central Europe. In several cases, evidence for short-term (100-kyr scale) forced regressions, independent of basinal structural activity, suggests small-scale eustatic falls at rates which, as presently understood, can not be explained other than by a glacio-eustatic mechanism.

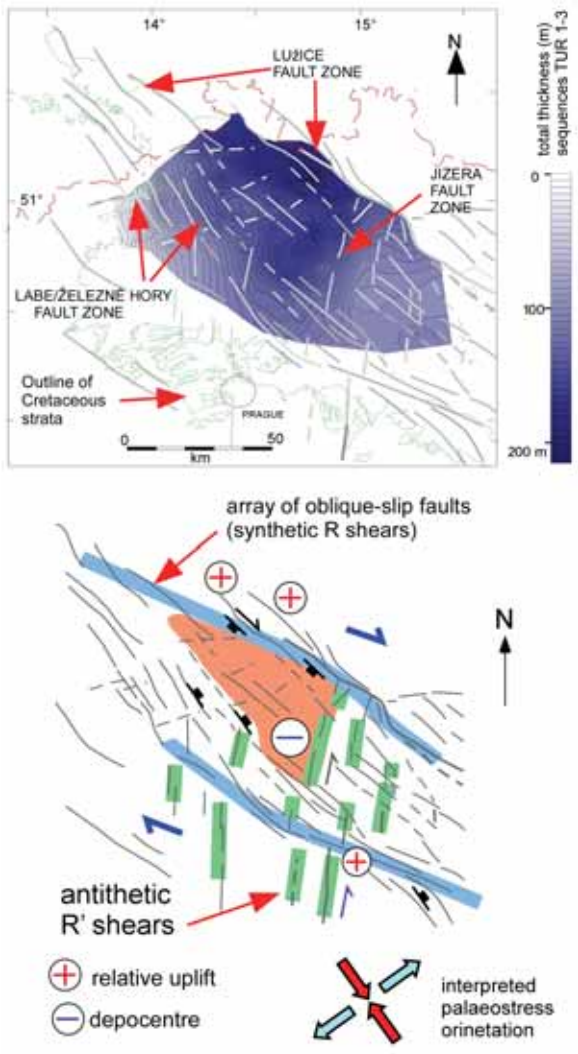

Figure 2

Top: isopach map showing the cummulative thickness of sequences TUR 1-3, compared with positions of the main fault zones. Note that the main accummulation of clastics fills a depocentre defined by the Labe-Železné Hory Fault Zone and the antithetic Jizera Fault Zone. Bottom: interpretation of the depocentre formation during this time due to interaction of the synthetic and antithetic oblique-slip faults of the Elbe Line and the Blanice-Rodl line. Interpreted prevailing orientation of the principal horizontal stress during the Turonian is shown.

I.G. research staff involved:

D. Uličný, J. Laurin

Reference:

Uličný, D., Laurin, J., and Čech, S., 20 Controls on clastic sequence geometries in a shallow-marine, transtensional basin: the Bohemian Cretaceous Basin, Czech Republic. *In revision, Sedimentology.*

Processes of magma emplacement and related fabric development

Kinematics and dynamics of magma ascent and emplacement can be deduced from the final magmatic fabrics and structures around magmatic bodies. Magmatic fabric pattern can provide crucial information about the internal magmatic processes, their timing relationships, mechanical coupling between magmatic processes and regional tectonics.

Our research is focused on detailed study of internal fabrics of various magmatic bodies (e.g. lava domes, laccoliths and plutonic bodies) and involves field-oriented structural geology and analogue modelling, which is combined with petrologic, geochemical, and numerical studies. The following two chapters represent our new data from the field structural studies and analogue modelling approach.

1. Analogue modeling using AMS – Internal fabric development during emplacement of lava domes

Analogue modeling is an important approach in geosciences that helps understanding of the mechanisms that contribute to the generation of finally observed structures. Internal flow/deformation pattern in analogue models of simple extrusions was investigated by means of AMS (anisotropy of magnetic susceptibility) fabrics.

In the first series of experiments, a simple manual squeezer was used to mobilize the weak plaster to vertically rise. In this way a columnar – "diapiric like" body supported by surrounding sand was formed (Kratinová et al., 2006; Kratinová, 2007). Magnetite dust homogenously admixed into weak plaster generates AMS signal that can be measured from drilled cores after the models solidify. In the second series of experiments, scaled analogue modeling using hydraulic squeezer was used to evaluate the fabric development in lava extrusions (Závada, 2007). Models of plaster extrusions well correspond in evolution to natural domes built of lavas with different crystal content like crystal rich dacites of Mt. Unzen or Mt. St. Helens. Their internal fabrics are also consistent with fabric pattern in one particular trachyte extrusion in the České Středohoří Mts. (Závada, 2007).

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Kratinová Z., 2007. Magmatic fabric development and overprints in granites: quantitative analysis and analogue modeling. *PhD Thesis. Institute of Petrology and Structural geology. Charles University in Prague.*

Závada P., 2007. Mechanisms of deformation and fabric development in rocks with low melt content. *PhD Thesis. Institute of Petrology and Structural geology. Charles University in Prague.*

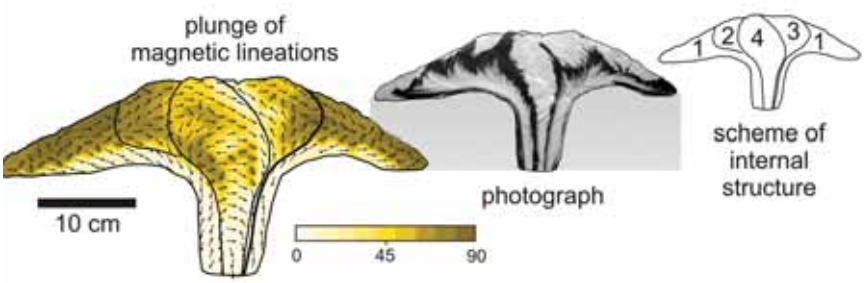

Figure 1

Experimental extrusion. The orientation of magnetic lineations indicate the flow direction (arrows show plunge direction, contours its inclination).

2. Magmatic fabric development and overprints in granites

Granite magmatism represents an important geological process that drives heat and mass transfer in the crust, controls crustal rheology and regional deformation. Recent projects are focused on detailed study of magmatic fabrics in Západokrušnohorský granite pluton in Bohemian massif and on granites in Vosges Mountains (Kratinová, 2007).

Three successive granites in the Vosges Mountains emplaced along major regional shear zone were studied by structural analysis, microstructural, geochronological and numerical methods. A new model of emplacement of granite sheets (the Thannenkirch, Brézouard and Bilstein granites) in transtensional setting (Kratinová et al., 2007) has been presented on the basis of the detailed AMS (anisotropy of magnetic susceptibility) fabrics. The study shows that the emplacement of successive granites was controlled by the pre-extensional syn-convergent orogenic structure and that the deformation was highly partitioned leading to the development of zones of margin-parallel wrench-dominated fabrics and extension-parallel pure shear-dominated fabrics. Detailed microstructural analysis based on EBSD (electron back-scattered diffraction) and microstructural observations, complemented by the new geochronological data of the Thannenkirch granite and thermal modeling discusses the development of asymmetrical cooling history, direction of successive emplacement and asymmetrical evolution of the fabric pattern.

References

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Kratinová Z., 2007. Magmatic fabric development and overprints in granites: quantitative analysis and analogue modeling. *PhD Thesis. Institute of Petrology and Structural geology. Charles University in Prague.*

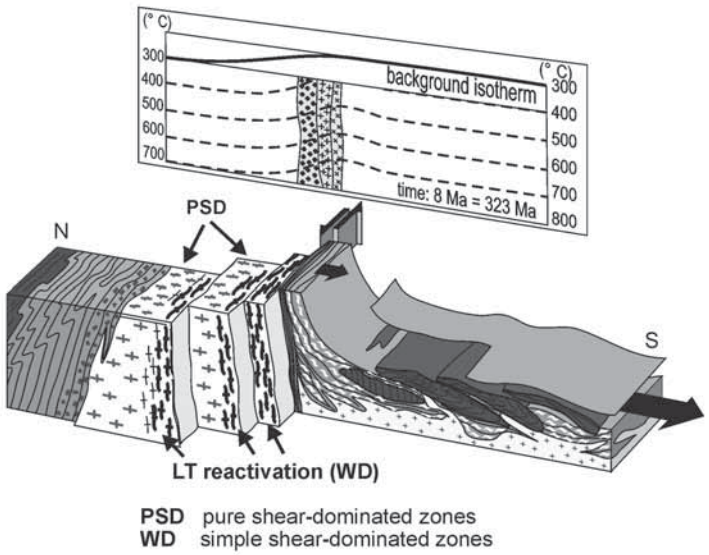

Figure 2

The interpretative 3D block-diagrams showing the evolution of internal fabrics in the successive emplacement of three granite sheets in the Vosges Mountains. The upper diagram documents the temperature evolution of exhumed crustal zone immediately after the emplacement of the third granite. "LT reactivation" designates "low-tempertature reactivation."

Non-double-couple mechanisms in induced seismicity: mining and oil & gas industry

The traditional assumption about a seismic source as a double couple (DC) can represent a serious limitation for describing mechanisms of seismic events induced by mining and hydro-fracture experiments in oil and gas industry, as well as during fluid injection into geothermal wells. In mining conditions (i), more general process than a shear slip can occur due to stress concentration on mined-out areas. During injection experiments (ii), the environs of the well is fractured by the pressurized fluid and tensile cracks can be created.

(i) We processed P and S amplitudes from five seismic events recorded at Driefontein gold mine in South Africa (Šílený & Milev 2007). All events display non-DC mechanisms, which are significant at 95% considering the errors in the data. The source mechanisms are in agreement with the underground mining and geological structures. Event 5 has a sub-vertical pressure single dipole complemented by an implosion, which is the body force equivalent of a collapsing horizontal crack or a burst of a pillar supporting the hanging-wall of a mined-out area. Events 1 and 3 are close to a pressure single couple. All three events are located on pillars. Event 4 is mostly DC accompanied by a compensated compressive dipole, which may be associated to nearly vertical dip-slip along a fault in the hanging-wall. This event is located on the margin of a wide pillar, which supports the interpretation.

(ii) Hydro-fracture experiments are a tool for revitalizing wells in oil and gas industry and increasing the production. They induce seismic activity in the vicinity of the well, which can be advantageously used for mapping the advance of the fracturing and revealing its type. Following the latter goal, we have inverted polarity and amplitude information of representative microearthquakes to investigate source mechanisms of seismic activity in the Carthage Cotton Valley, Texas, gas field. With vertical arrays of four and eight geophones in two monitoring wells, respectively, we were able to reliably determine source mechanisms of the strongest events with the best signal-to-noise ratio. Our analysis indicates predominantly non-double-couple source mechanisms with positive volumetric component consistent with opening cracks oriented close to expected hydraulic fracture orientation. Our observations suggest the induced events are directly the result of opening cracks by fluid injection, in contrast to previous studies where the seismicity is interpreted to be primarily shearing caused by pore-pressure diffusion into the surrounding rock or associated with shear stresses created at the hydraulic fracture tip (Šílený et al. 2007).

Microseismic monitoring datasets are frequently limited to a single array of geophones

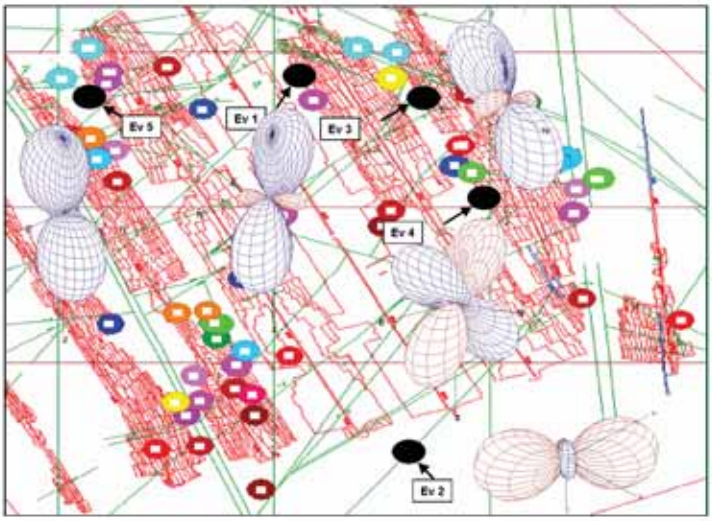

Figure 1

Mechanisms of five seismic events from Driefontein gold mine, S.Africa, in wireframe plot of P-radiation pattern (red – compressions, blue – dilatations) on the background of the mine map (red lines – margins of the excavated patches, green – tectonic lines in the site)

in a borehole. If this borehole is vertical and the medium is laterally homogeneous then seismic waves arrive along a single-azimuth from source to all receivers. In this case, Vavryčuk (2007) showed that the dipole perpendicular to the plane of stations and the hypocenter cannot be resolved. Thus, moment tensor inversion for all six components of the general source mechanism is underdetermined. A solution of this problem is to invert only for the moment tensor components which are constrained by the observed data (Jechumtálová and Eisner 2007). It can be done in coordinates based in the plane of the receivers and the hypocenter. Then, the class of source mechanisms corresponding to the data is constructed by combining the 5 constrained MT components with an arbitrary value of the 6th one. We tested this method on a synthetic dataset (Fig. 3). As input data we used source model of crack opening along the east-west direction. This test demonstrates that crack-opening seismic event recorded by a single vertical array can be misinterpreted as a pure-shear seismic event. Moreover, neither its orientation is well constrained (upper right plot in Fig. 3). It indicates that best fitting a-priori assumed shear mechanism inverted by using a single vertical array can provide misleading information.

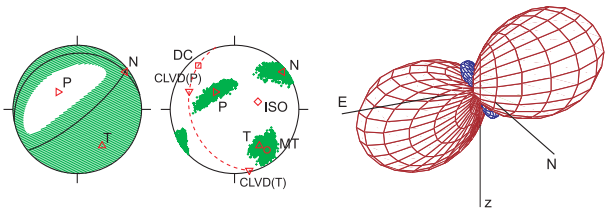

Figure 2

Characteristic mechanism at one of the clusters of seismic events induced by injecting the water into the production well. It is dominated by a sub-horizontal tensile dipole striking SSE-NNW, i.e. roughly perpendicularly to a local branch of the mostly linear locus of the micro-earthquake hypocenters mapping the direction of maximum horizontal stress in the zone. It indicates a tensile fracture opening against the minimum compression. Left – P-radiation pattern (green area – compressions) in equal-area projection of the focal sphere, right – the same as a wire-frame plot (red – compressions, blue – dilatations), center – Riedesel & Jordan display of the moment tensor (MT) decomposition into the isotropic part (ISO), double-couple (DC) and compensated linear vector dipole (CLVD) together with confidence zones of the principal axes T, N and P, and the confidence zone of the MT decomposition.

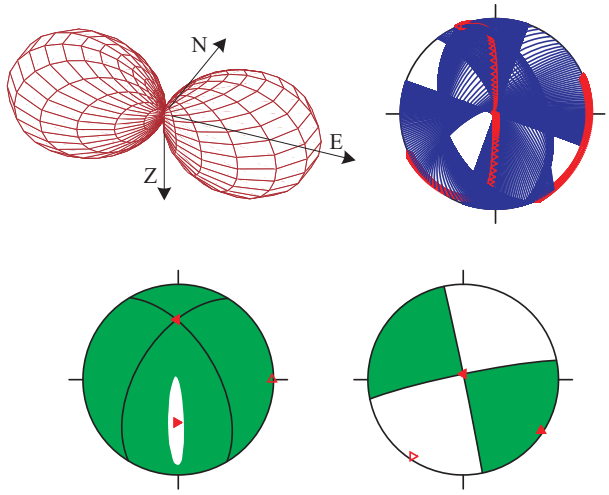

Figure 3

Test of source mechanism inversion in a single vertical borehole. Upper left plot represents radiation patern of crack opening in the east-west direction – the input model. Upper right plot represents all possible fault plane orientations fitting all seismic data with exactly the same misfit. Lower plots represent two possible inversion results.

I.G. research staff involved:

Jan Šílený, Václav Vavryčuk, Zuzana Jechumtálová

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Anisotropy as an origin of non-double-couple focal mechanisms of earthquakes at the KTB superdeep borehole

Moment tensors of microearthquakes induced during the 2000 injection experiment at the KTB deep drilling borehole in Germany contain significant non-double-couple components. The double-couple (DC) is on average 60% and the non-double-couple (non-DC) is 40%. The non-DC components contain both the isotropic (ISO) and compensated linear vector dipole (CLVD) components. The mean value of ISO is 1.5%, the mean value of CLVD is -5.7%. The predominantly negative CLVD components are inconsistent with the concept of the non-DC mechanisms as a result of tensile faulting due to fluid injection into the rock.

The main origin of the non-DC components is probably anisotropy in the focal area. Theoretical analysis reveals that focal mechanisms in anisotropic media are more complicated than in isotropic media: shear faulting produces DC mechanism in isotropy, but generally non-DC mechanism in anisotropy. The non-DC mechanism can comprise both the ISO and CLVD components. The amount of the ISO and CLVD components depends on strength and symmetry of anisotropy and on the orientation of faulting. Adopting four alternative models of anisotropy obtained by other seismic measurements at the KTB, we have employed the non-DC components for estimating an optimum orientation of anisotropy in the focal area. The optimum orientation of the symmetry plane of anisotropy is nearly vertical with a strike of N335°-340°E. This strike coincides well with the strike of 330° typical for many major lithological units and faults and with the orientation of the transversely isotropic model inferred by other authors. After removing the anisotropy effects from the moment tensors by calculating the source tensors, the distribution of ISO is significantly narrowed. This indicates predominantly shear, but not tensile faulting.

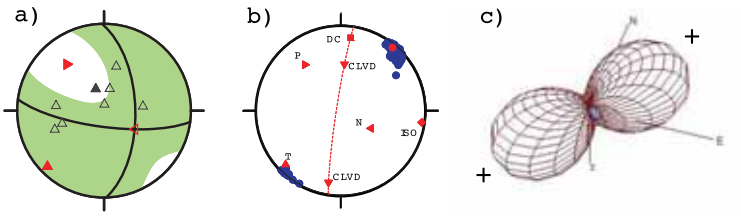

Figure 1

An example of an extensive mechanism with positive ISO and CLVD components: (a) the optimum fault-plane solution, (b) the distribution of 100 solutions (blue dots) and the optimum solution (red dot) in the Riedesel-Jordan projection, and (c) the P-wave radiation function for the optimum solution. The green area in plot (a) marks the zone of compressions. The principal axes are marked by red triangles. The solid/open triangles mark stations with the P-wave dilatation/compression. Clustering of solutions (blue dots) in plot (b) testifies the stability of the solution. The plus and minus signs define the polarity of the radiated P wave amplitude.

I.G. research staff involved:

Václav Vavryčuk, Zuzana Jechumtálová, Petr Kolář, Jan Šílený

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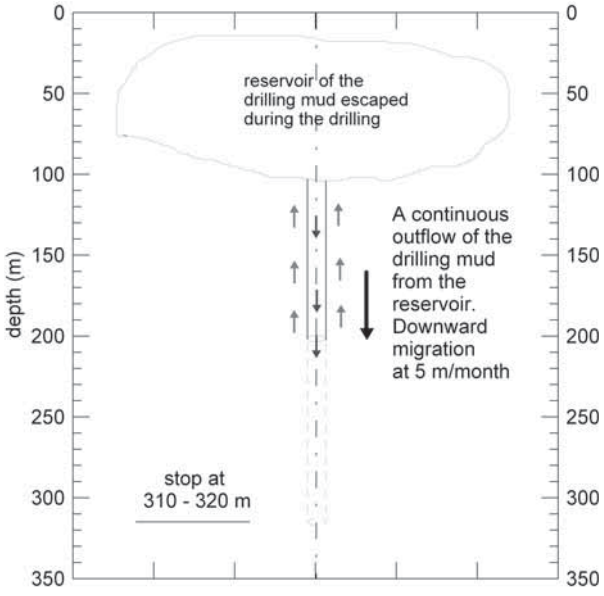
Geothermal research of the impact structure Chicxulub

The geothermal research of the Chicxulub impact structure on the Yucatan Peninsula, Mexico, included repeated temperature logs of the 1.5 km deep borehole Yaxcopoil-1, which were done 0.3-0.8, 15, 24, 34 and 50 months after shut-in of drilling operations. A gradual distortion of the linear temperature profile by a cold wave of 0.8–1.6 °C amplitude was detected propagating downward from 145 m to 317 m within the observational period of 50 months. The analysis of the logs helped us to formulate a hypothesis that the transient features of the temperature – depth profiles are related to downward migration of drilling mud, which escaped during the drilling of the borehole into the surrounding, strongly karstified rock. The thermal effects of the migrating fluid were evaluated by solving numerically the heat conduction-convection equation in appropriate geothermal models (Fig.1).

The model of the drilling mud migrating as an isolated big drop turned out to be quite feasible and its parameters to be constrained well by the observed temperature logs. Namely: (i) the vertical extent of the downward migrating fluid body is about 10 m, maybe increasing within the observational period of 33 months by a factor of 2, (ii) the horizontal extent of the body must be at least 5 – 10 m, i.e. by order(s) of magnitude larger than diameter of the borehole, (iii) the average speed of the migration is about 5 m/month and (iv) the fluid must migrate through a highly porous rock (70% - 80% porosity or more). This high porosity implies very high effective permeability of the subsurface, which poses a high danger of contamination of the thin freshwater aquifer, the sole-source of freshwater for the Yucatan region, by human activities.



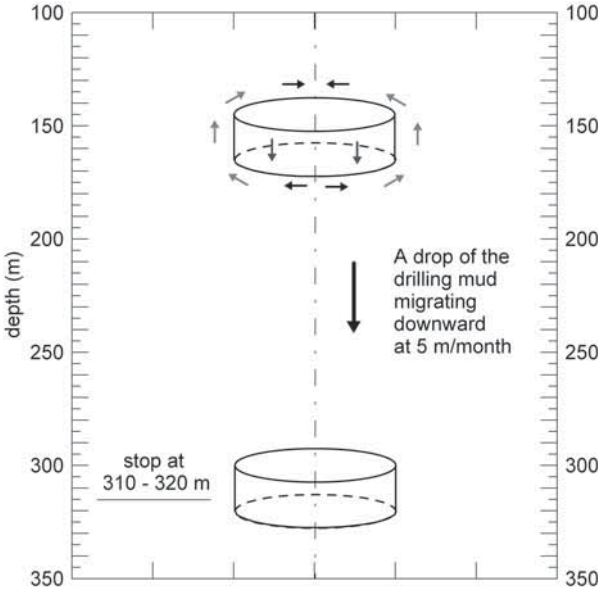


Figure 1

Two conceptual models of the downward drilling fluid migration considered in the simulations of the temporal changes of temperature observed in borehole Yaxcopoil-1.

I.G. research staff involved:

Jan Šafanda, Vladimír Čermák

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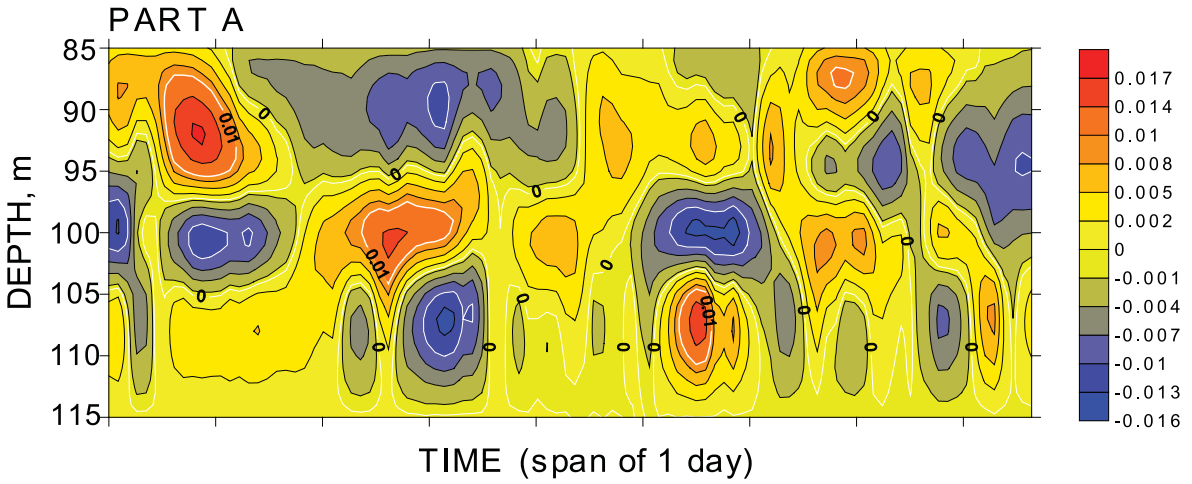
High-resolution temperature monitoring in a borehole

Thermal convection of fluid under different boundary conditions is an important physical problem in a variety of contexts. It has been extensively studied, both theoretically as well as in laboratory, in the field of nonlinear dynamics. Temperature data obtained in boreholes may suitably serve as critical input to many fields of engineering, exploration, and research. Except of large scale environmental signals borehole temperature logs may contain also finer signals associated with e.g. the heat transfer in a compositionally and structurally heterogeneous subsurface as well as with small scale convection in a water filled borehole.



To detect the existence of borehole convection, we focused on a high resolution temperature monitoring in the Spořilov hole. The hole (located on the campus of the Institute of Geophysics, Prague) was drilled in the early nineties, it is 150 m deep, 10 cm in diameter, penetrated consolidated sediments and is equipped by a plastic tube (5 cm in diameter) to prevent any disturbances due to ground water movement. Mean temperature gradient is 0.0192 mK/m. Several monitoring experiments were performed since 2004. All displayed intermittent, non-periodic oscillations of temperature of up to several hundredth of degree with sharp gradients and large fluctuations over all observed time intervals (Čermák et al., 2007a,c), which were interpreted as an "oscillatory" convection occurring due to instability within the horizontal boundary layers between the individual convectional cells (Čermák et al., 2007b). Temperature-time series showed a complex apparently random oscillation pattern with amplitude of up to 0.025 K. Irregular temperature variations characterized by larger oscillations may alternate with relatively "quiet" intervals. The character of the oscillation may vary both in depth as well as in time and the transition between two distinct regimes may be sudden. Statistical analysis suggested the existence of a quasi-periodic intra-hole oscillatory convection. The convection has two-frequency structure, when short period oscillation of about 10 to 30 minutes are superposed on longer variations of up to several hours (Čermák et al., 2007a). At certain conditions, so far not fully understood, the convection may practically stop; the temperature remains within 0.001-0.002 K for a period of several days when the convection suddenly resumes.

The process of intra-hole convection, responsible for the fine scale temperature variations, can be discriminated as a generally deterministic process. This process operates on rela-

tively short time scales with the characteristic times varying from a few seconds to days. In the presence of geothermal gradient the relatively heavier cold fluid located above warmer and lighter fluid is forced to move downwards, the release of potential energy provides kinetic energy for the motion and the system becomes unstable. This instability is opposed by the frictional action of the fluid viscosity and thermal conductivity tends to equalize the temperature difference between the rising warmer and the sinking colder water masses. The motion thus occurs only when the destabilizing effect of the temperature difference is strong enough to overcome these obstacles.

The use of formal statistical methods to interpret and describe the results of borehole monitoring together with its visualization can help to better understand the dynamics of this process. Together with traditional methods, such as Fourier analysis, the recently introduced powerful methods such as recurrence plot (RP) and/or local growth of the second movement (LGSM) were used (Čermák et al., 2007b,c) to better detect very subtle patterns in time series that can be spotted on a classical visualization scheme (Figure 1)

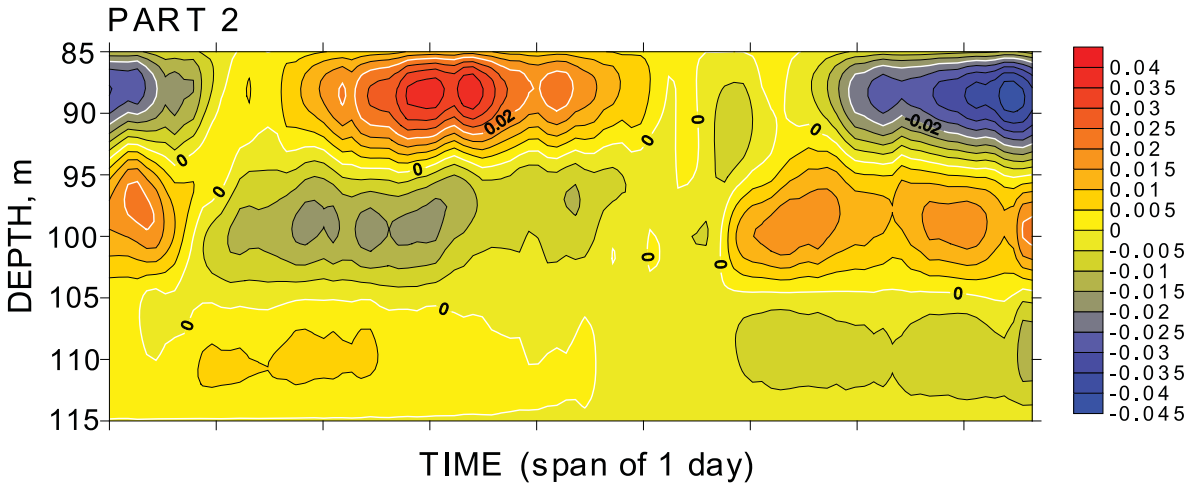


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Figure 1

Example of a high-resolution temperature mapping performed at the depth interval 85 to 115 m in the Spořilov hole. Two "one-day" time spans are shown to demonstrate the relatively quiet (right) and the relatively "noisy" (left) temperature regime. Isolines are labelled in K.

Repeated temperature logs from Czech, Slovenian and Portuguese borehole climate observatories

The repeated temperature logs carried out within 6 boreholes at the sites of the Czech , Slovenian and Portuguese borehole climate observatories and their surroundings within a time span of 8 – 20 years (1985 – 2005) revealed subsurface warming in all the boreholes amounting to 0.2 – 0.6 °C below 20 m depth. The compatibility of the observed temporal changes of subsurface temperature with surface air temperature (SAT) series measured in Prague (since 1771), Ljubljana (since 1851) and Lisbon (since 1856) was checked by comparing repeated temperature logs with synthetic profiles that were calculated using SAT series as forcing functions. Both the observed and the synthetic differences reveal a warming, but the degree of quantitative agreement varies appreciably. In the Portuguese and the Czech boreholes the synthetic difference approximates the observed difference quite well below the depth of 40 – 50 m. By contrast, in Slovenian boreholes V-8/86 Malence and V-7/85 Topličnik, the synthetic difference is larger that the observed difference. Relatively good agreement between the two differences appears in the remaining two Slovenian boreholes ŠT-1/85 Štatenberg and BR-1/86 Brdo. The largest difference was observed at the Czech observatory, 0.6°C at 20 m (warming rate of 0.050 °C/yr) (Fig.1), which is two times more than the simulated difference suggests. Therefore, it could be that subsurface temperature at the station is influenced by new structures built within the campus of the Institute of Geophysics within the last 10 – 20 years and/or by other components of infrastructure (asphalt roads, a playground etc.) built 40-50 years ago. This suspicion is supported by an otherwise good correspondence of the two differences at depths below 50 m. We carried out a quantitative analysis of these effects by solving numerically the heat conduction equation in a three dimensional geothermal model of the borehole site.

It turned out that the anthropogenic structures influence the temperature in the borehole quite strongly. Their warming effect in the uppermost 40 m is nearly as large as the warming due to increasing SAT. This fact explains very well the discrepancy between the GST and SAT warming rates in the last decades. It also means that the coupling between the air and ground temperatures is quite strong at this site.

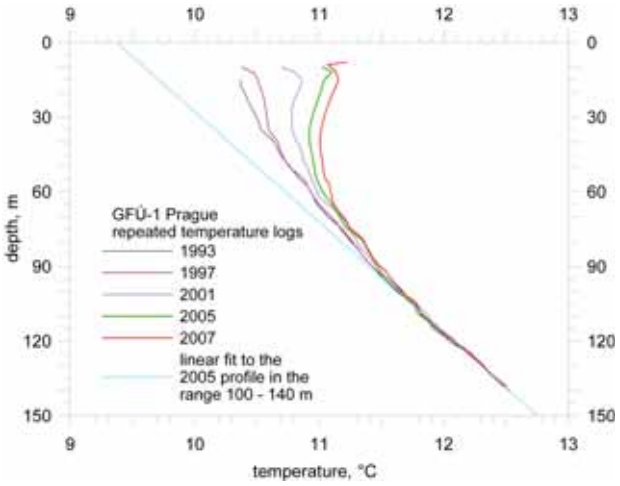

Figure 1

Long-term subsurface warming observed by repeated temperature logs of borehole GFÚ-1 in Prague.

I.G. research staff involved:

Jan Šafanda, Petr Dědeček

References

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Environmental magnetism on regional scale

We have finished complex research of imissions on regional scale over the territory of the Krkonoše Mts. National Park which belongs to regions within the Czech Republic characterized by relatively low levels of atmospheric fallout. Based on measurements of magnetic susceptibility of topsoils, detailed magnetic map for the whole region was compiled. Magnetic mapping is based on our previous laboratory studies of magnetic and mineralogic parameters of a large set of vertical soil profiles from this region (Kapička et al., 2003).

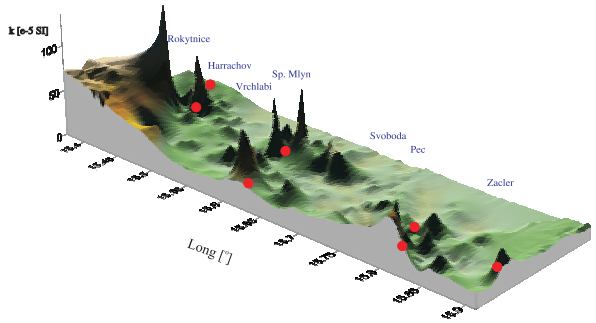
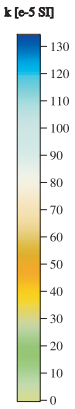


Figure 1
Spatial distribution of topsoil magnetic susceptibility over the area of the Giant Mts. National Park

Spatial distribution of topsoil volume magnetic susceptibility is shown in Fig. 1, with the values ranging from 1.2×10^{-5} SI to 95.5×10^{-5} SI. Distribution of all values, representing 462 measured sites, is close to log-normal. For the major part of the studied area, relatively low values from the range of $20 - 25 \times 10^{-5}$ SI were typically found.

Consistently enhanced values of magnetic susceptibility were observed on the southern and south-western margin of the Park, where several administrative centers are located. Extreme values within the Park are associated with the tourist centers of Harrachov, Špindlerův Mlýn and Pec pod Sněžkou. In these cases, local sources of pollution are responsible for the enhanced topsoil susceptibility. Although the magnetic susceptibility in these areas is very high, these anomalies do not extend far away, are well bordered and are not interconnected. These results can be interpreted as follows: one of the possible pollution sources, long-distance transport of pollutants, affects mainly topsoils in the western part of the region. In addition, soil contamination from local sources of pollution within the National Park is very important.



We found moderate correlation between magnetic susceptibility of topsoils and concentrations of Pb. Therefore, in this specific case, fast and low-cost magnetic mapping can be used as approximate method for monitoring the contents of Pb in topsoils in this area.

Our results represent the first complex information about the distribution of atmospherically deposited dust particles and may serve as a starting point for the design of future monitoring system in this region.

I.G. research staff involved

A. Kapička, E. Petrovský, H. Fialová

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Inverse problems in geophysics solved using artifical neural networks

The aim of the project is to develop a new algorithm for the solution of complex inverse problems. Most of the geophysical inverse problems are difficult tasks, encumbered by the non-linearity of the underlying theory and non-uniqueness of the solution, often involving high-dimensional data and/or model spaces, and based on computationally complex, often iterative, and highly time-consuming forward modeling procedures that have to be carried out repeatedly within an inversion run. For coping effectively with as many of those aspects as possible development of new and efficient tools for the inversion of geophysical data is still in great demand.

The goal of the present project is to elaborate, test and implement the ANNO (Artificial Neural Network Optimization) algorithm. The key element of ANNO is an artificial neural network employed as an universal interpolating engine applicable to an arbitrary irregular network of nodes and to the space of arbitrary dimension.

ANNO is based on the traditional concept of data (d) and model (p) spaces related by a forward modeling operator, d = F(p). Within ANNO, the unknown inverse mapping p = G(d), $G = F^{-1}$, is approximated numerically by means of a neural network that is trained to respond, if excited with measured data, with appropriate parameters in the model space. Though the choice of the particular approximating neural network is not unique, within the ANNO algorithm the network composed of radial basis functions is preferred because of their simple topology and easy learning. ANNO is operating iteratively on a population of individuals, a single individual being any associated model-data pair. The entire population at the current iteration is used for on-line re-learning the neural network. A relatively sparse initial population is generated randomly throughout the search space. In each successive iteration, new individuals are generated by using the current neural network, and, additionally, the population is adapted according to specific rules so that the precision of the interpolation is enhanced. In this way, the population becomes more concentrated in domains closer to the solution, the accuracy

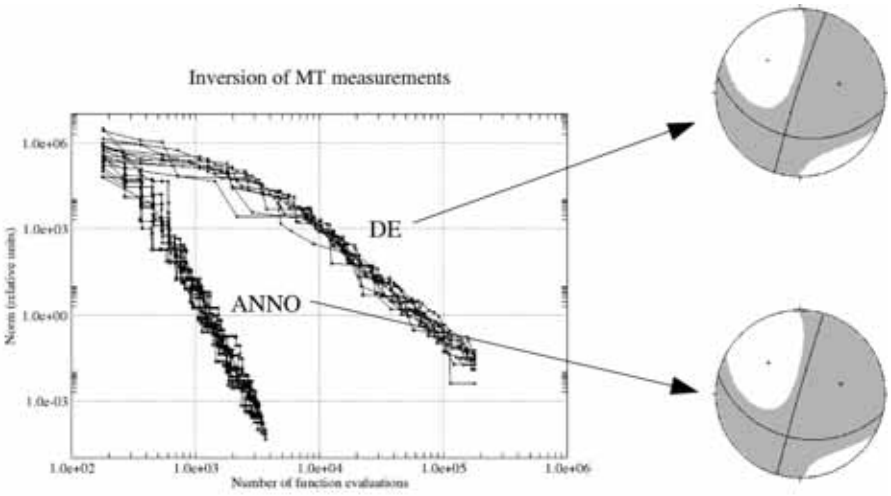

Figure 1

Example documenting computations of the seismic moment tensor (MT) inversion. Convergence curves of 10-times repeated MT inversions of synthesized error-free data using ANNO and DE optimizers, and results of real MT inversions (right). Both results are nearly identical (see the two beach balls), but ANNO solution has been achieved much faster.

of the approximation by the neural network increases, and estimates of the solution improve with the number of iterations. The best model from the final population is considered a candidate solution to the inverse problem.

The ANNO algorithm has been both tested on synthetic problems (Málek et al. 2007) and applied to invert the travel times for an optimum velocity model (Růžek et al. 2007a) as well as to invert the relative P/SH amplitudes for components of the seismic moment tensor (Růžek et al. 2007b). Comparison of the results with those obtained by other optimization approaches shows that ANNO is an efficient and robust algorithm.

The ANNO project is supported by the Grant Agency of the AS CR, contract No. IAA200120701. As a part of the project, a multi-platform implementation of ANNO is considered and a detailed documentation will be provided. Free, non-restricted use of the algorithm by researchers and engineers from both science and industry will be made possible.

I.G. research staff involved:

Bohuslav Růžek, Petr Kolář

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Wave propagation

Seismic waves propagating in the Earth's interior are affected by anisotropy and attenuation. It is, therefore, important to study the effects of anisotropy and attenuation on seismic wave propagation in realistic structures.

First-order ray-theory Green function for inhomogeneous weakly anisotropic media

Seismic anisotropy in the Earth is often weak (this explains success of seismic studies based on assumption of isotropy of the Earth's interior), therefore, it is desirable to develop efficient methods for the computation of seismic wave fields in inhomogeneous, weakly anisotropic structures. Combination of the standard ray method with the perturbation theory, in which deviations of anisotropy from isotropy are considered to be the first-order quantities is such a method. Basic idea of the approach is substitution of the exact expressions in ray-tracing and dynamic ray-tracing equations and the Green function by their approximate, first-order counterparts. This has several important consequences. In most practical applications, the method yields results of sufficient accuracy with considerably improved efficiency and lowered demands for computer memory. The ray-tracing and dynamic ray-tracing equations simplify considerably. For higher-symmetry media, they differ only slightly from those for isotropic media (they thus allow their simple and straightforward substitution in existing codes). The method takes into account coupling of the two S waves propagating in anisotropic media. If anisotropy vanishes, all equations reduce to standard, exact ray-tracing and dynamic ray-tracing equations, and to the standard ray-theory Green function for isotropic media. For details see Pšenčík & Farra (2005, 2007) and Farra & Pšenčík (2008).

Wave propagation in viscoelastic anisotropic media

Wave propagation in viscoelastic anisotropic media differs in many aspects from wave propagation in perfectly elastic media or from viscoelastic isotropic media, see Červený & Pšenčík (2006a, b; 2008a, b). In an isotropic dissipative medium, the attenuation properties of rocks are usually specified by the quality factor Q, which is a dimensionless, direction-independent, real-valued, scalar quantity. A similar, scalar, but direction-dependent quality factor Q can also be derived for anisotropic dissipative media. Červený & Pšenčík (2008a, b) propose for weakly inhomogeneous plane waves propagating in arbitrarily anisotropic, weakly dissipative media, a simple approximate formula, which is independent of inhomogeneity of considered wave. It may be thus used as convenient measure of dissipative properties of rocks.

Numerical example illustrates behaviour of the Q^{-1} in a model of a TI, weakly dissipative sedimentary rock. Fig.1 shows plots of Q^{-1} as a function of the ray angle (direction of energy flux). Red corresponds to P wave, blue to both S waves. The egg-shaped curve corresponds to the SH wave, the internal curve with loops corresponds to SV wave. S-wave attenuation is generally larger than P-wave attenuation; compare the scales of P- and S-wave plots. The most remarkable phenomenon in Fig. 1 are the smooth inner loops on the SV-wave curve in the S-wave diagram. The loops are situated exactly at the ray angles of outer loops of the SV-wave energy-velocity curves. At the loops, the values of Q^{-1} attain minimum values. Consequently, the attenuation of SV waves is minimum in regions of the loops, which are regions of high amplitudes.

Asymptotic Green function in viscoelastic anisotropic media

The asymptotic Green's function in viscoelastic media is formally similar to that in elastic media, but its computation is more involved. The stationary slowness vector is, in general, complex valued and inhomogeneous. Its computation involves finding two independent real-valued unit vectors which specify the directions of its real and imaginary parts and can be done either by iterations or by solving a system of coupled polynomial equations. When the stationary slowness direction is found, all quantities appearing in the Green's function such as the slowness vector, polarization vector, phase and energy velocities and principal curvatures of the slowness surface can readily be calculated.

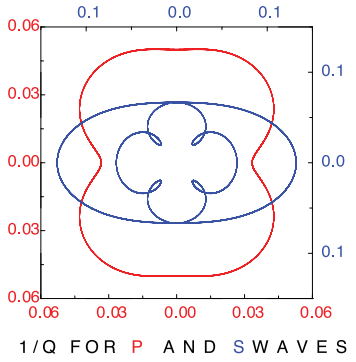

Figure 1

Inverse value of the quality factor Q as a function of the ray angle. P wave (red) and S waves (blue) in a plane of symmetry of a TI medium. Note the inner smooth loops on the curve corresponding to the SV wave. The loops correspond to the lowest attenuation.

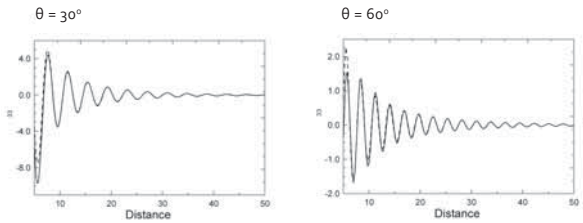

Figure 2

The real part of the G_{33} component of the exact (solid line) and asymptotic (dashed line) P-wave Green function in Carbon/epoxy composite. The Green functions are for a ray deviating from the vertical by angle θ = 30° and θ = 60°. The distance is normalized to $\sqrt{a_{33}^R}/\ \omega$ .The Green function is in 10^{-10} m/s.

The formula for the asymptotic Green's function was numerically checked against closed-form solutions for isotropic and simple anisotropic, elastic and viscoelastic models, see Fig.2. The computation of the P-wave Green's function in two realistic materials with a rather strong anisotropy and absorption indicates that the asymptotic Green's function is accurate at distances greater than several wavelengths from the source. The error in the modulus reaches at most 4% at distances greater than 15 wavelengths from the source. For more details see Vavryčuk (2007a, b).

I.G. research staff involved:

Ivan Pšenčík, Václav Vavryčuk

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Stochastic sampling for the inversion of magnetotelluric and geomagnetic induction data

Bayesian sampling approaches, based on assimilating the prior model information and the experimental data available, aim at providing estimates of both the model parameters and their uncertainties by generating model samples distributed according to the true posterior probability of the model parameters conditioned on the data. Though still computationally very demanding in most of the cases, the Bayesian sampling by the Monte Carlo method with Markov chains (MCMC) has recently become feasible for several model classes commonly used in interpreting data of practical electromagnetic depth soundings. We have developed and practically tested algorithms for the application of the Bayesian Monte Carlo stochastic sampling approach to the solution of non-linear inverse problems of the electromagnetic induction in the Earth for three particular model settings – the anisotropic layered Earth, 2-D conductivity distribution in the Earth, and quasi-3-D conducting structures approximated by a laterally non-uniform thin sheet. We have implemented two alternative MCMC sampling procedures, the standard Gibbs sampler and a new Single Component Adaptive Metropolis algorithm. The latter algorithm shows particularly promising in 2-D and quasi-3-D model settings, as it effectively reduces the number of costly direct solutions in a single MCMC iteration step.

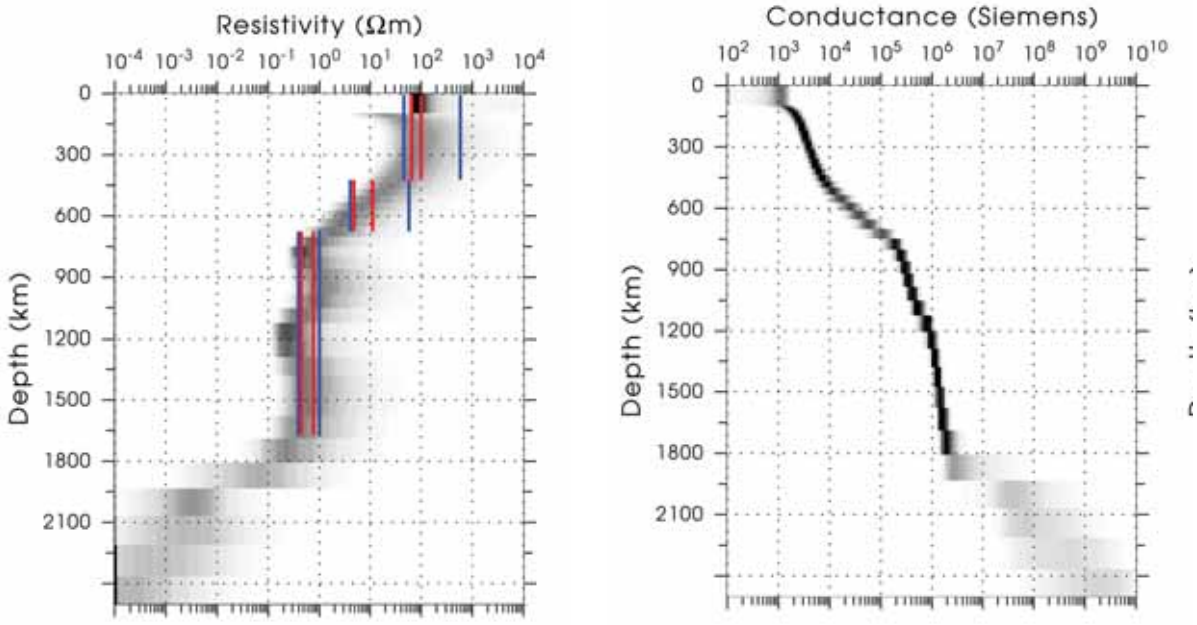
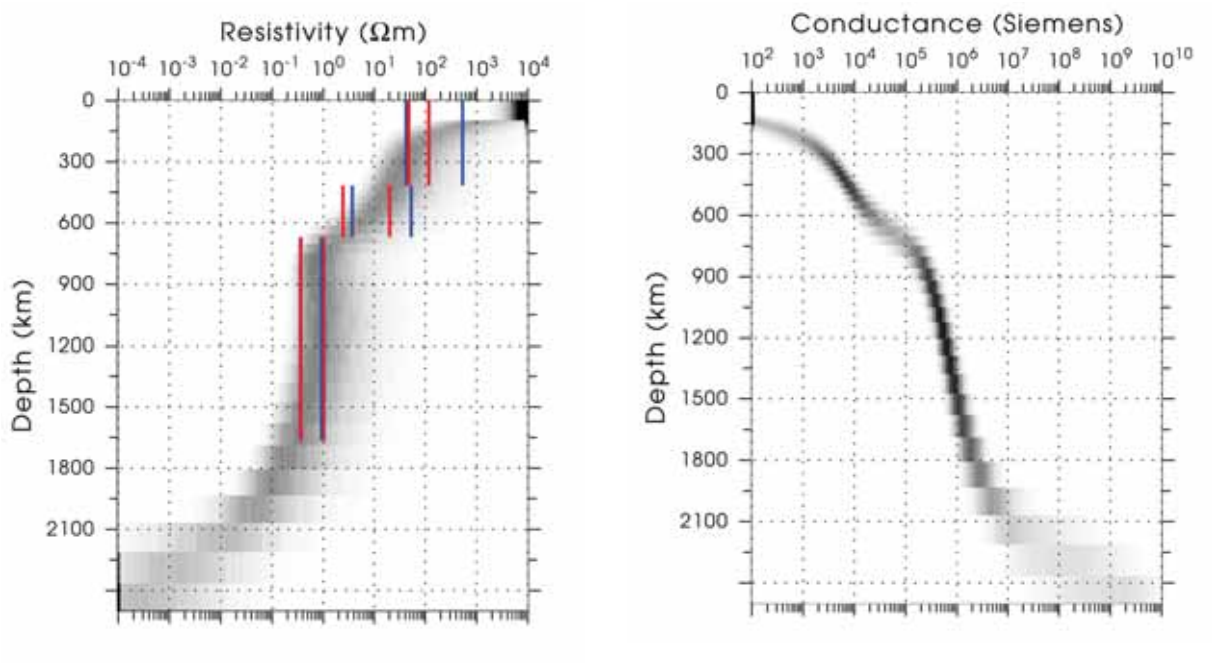


Figure 1

Upper mantle resistivity and conductance models from the MCMC inversion of long-period geomagnetic induction data with structural prior assuming only that the conductance is a strictly increasing function of depth. Left: Gray-scale plots of sample probability distributions of the resistivity (left) and conductance (right) values from the inversion of a joint data set by Medin et al. (2007) and 90% χ^2-limits on average conductivity within three mantle zones derived from the sample models (red lines) and from a direct maximum likelihood procedure by Medin et al. (2007, blue lines).

Further computation savings can be achieved by applying special update techniques to the direct solution for weak conductivity changes that affect only a small number of cells in the model, or by updating the direct solution via linearization provided the parametric sensitivities can be computed at low enough costs.

In particular, modelling of long period geomagnetic data for the upper mantle electrical conductivity could benefit from the flexibility of the stochastic sampling with respect to the choice of the prior information. By avoiding the commonly used Occam roughness penalty in the inversion, we could get more realistic, less biased sample-based constraints on the average electrical conductivities in the mantle down to depths of about 1200 km from various geomagnetic data sets available (Figs. 1,2).



I.G. research staff involved:
J. Pek, V. Červ, J. Pěčová

Figure 2
Sample probability distributions of the resistivity and conductance from the MCMC inversion of our data set, consisting of induction responses from about 90 observatories for Sq-harmonics and from 45 observatories all over the globe for long period variations, along with the average resistivity bounds from Medin et al. (2007, blue lines) and from models from the Markov chain (red lines).

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Solar inertial motion and its relations to solar-terrestrial variability

Studies into the role and impact of the solar inertial motion on the solar and geomagnetic activities are of special importance, as they may help in assessing the natural variability of those phenomena by relating them to strictly predictable mechanical processes within the solar system.

The solar motion due to the inner planets (Mercury (Me), Venus (V), Earth (E), Mars (Ma)) has been calculated. We have found the following basic properties of this motion: the toroidal volume in which the Sun moves has the inner radius of 101.3 km and the outer radius of 808.2 km. The solar orbit due to the inner planets is 'heart-shaped'. The orbital points closest to the centre lie at the time distance of 1.6 years (584 days), on the average, and approximately coincide with the moments of the oppositions of V and E. The spectrum of periods shows the dominant period of 1.6 years (V-E) and further periods of 2.13 years (E-Ma) (25.6 months, QBO), 0.91 years (V-Ma), 0.8 years ((V-E)/2) and 6.4 years. All the periods are above the 99% confidence level. A possible connection of this motion with the mid-term quasi-periodicities (MTQP, i.e. 1.5-1.7 years) in solar and solar-terrestrial indices can be proposed (Charvátová, 2007)

The series of the geomagnetic index aa and the series of the Wolf sunspot numbers (W) have been processed in three intervals related to the three periods of the solar inertial motion (SIM) due to the giant planets: 1844-1905, 1906-1956 and 1957-2005. In the second interval, the Sun moves along the stable trefoil orbit, where the motion along one motion loop (arc) lasts 10 years. The orbits of the Sun in the first and the third intervals are of disordered type and differ one from another. The power spectra of both the solar and the geomagnetic activity in the central interval show the dominant period of 10.1 years and their patterns are very similar. The dominant period of the sunspot numbers (index aa) in the first interval is the period of 11.4 (11.3) years. In the third interval, the period of 10.7 (10.8) years was detected. The spectra for W and aa –index show significant differences between the first and third intervals. The best fit line for the second (trefoil) interval of solar and also of geomagnetic activity is the straight line (the line of stable character), while for the first and third intervals it is a second and third-order polynomial, respectively (Fig.2, Charvátová and Střeštík, 2007).

Possible interrelations between the 300-year record of the yearly sunspot numbers and the solar inertial motion (SIM) using the recently developed technique of the synchronization analysis have been studied. Phase synchroniza-

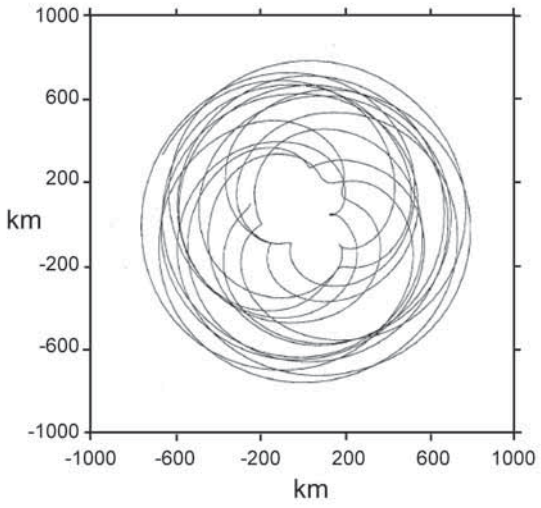
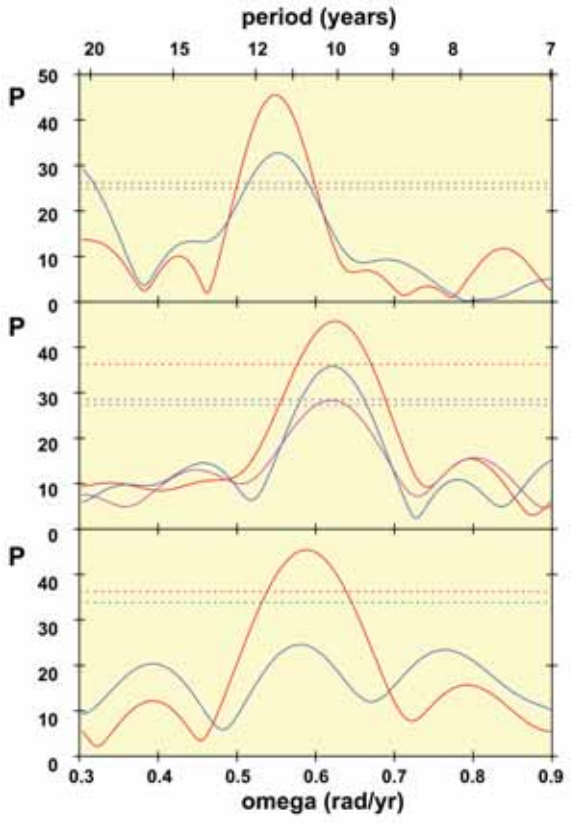


Figure 1

The solar orbit due to the inner planets (Mercury (Me), Venus (V), Earth (E), Mars Ma)) in the years 1995-2010, shown as the deviation in km from the inertial centre of the solar system. The orbit is "heart-shaped". The average time distance between the nearest points is 1.6 years (VE).

tion of the sunspot cycle and the SIM is found and statistically confirmed in three epochs (1734-1790, 1855-1875 and 1907-1960) of the whole period 1700-2000. The first and the third epochs correspond to the trefoil intervals of SIM, the central epoch contains one half of the trefoil. These results give quantitative support to the hypothesis that there is a weak interaction between the solar activity and the SIM (Paluš et al., 2007).



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Charvátová, I., 2007. The prominent 1.6–year periodicity in solar motion due to the inner planets, *Annales Geophys. 25, 5, 1227-1232.*

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Paluš, M., Kurths, J., Schwarz, U., Seehafer, N., Novotná, D. and Charvátová, I. 2007. The solar activity is weakly synchronized with the solar inertial motion, *Physics Lett. A, 365, 421–428, doi:10.1016/j.physleta.2007.01.039, 2007.*

Figure 2

Top: the spectrum for the first interval (1844–1905) has the dominant period of 11.3 years for the sunspot numbers (red line) and it has the dominant period of 11.4 years for the index aa (blue line). Middle: the spectrum for the second interval (1906-1956, trefoil interval) has the same dominant period of 10.1 years for the sunspot numbers (red line) and for the aa index (blue line). This corresponds to the duration of SIM along one motion loop (arc) (JS/2). The spectrum for the sunspot numbers from the previous trefoil interval 1728–1778 is added (lila line). Again, the dominant period of 10.1 years was detected. Notice that all the three spectra have very similar pattern.

Bottom: the spectrum for the third interval differs from that for the first interval (compare with top figure). It has the dominant period of 10.8 years for the sunspot numbers (red line) and of 10.7 years for the index aa (blue line).

Geoeffectiveness of the solar energetic events

The prediction scheme of geomagnetic disturbances can be divided, based on their input data, into schemes based on the knowledge of solar wind parameters and schemes based on information related to the events taking place on the solar disc. The first of them provide relatively good results with regard to the intensity of the forecast disturbances, nevertheless, since the solar-wind data are obtained at point L1, the warning time is mere 30-60 minutes. The time is too short to take steps to mitigate the negative consequences of such disturbances. The second of them enable the warning time to be extended to 1-3 days. The input data of these schemes are usually the information on the existence of a Coronal Mass Ejection (CME), its velocity and place of origin on the solar disc. Our forecast scheme is based on the analysis of the geoeffectiveness of energetic events observed on the solar disc in the years 1996-2004 (Bochníček et al.,2007). As opposed to the procedures named above, the input information of this scheme are not CME data, but the data on the X-ray flares accompanied by solar radio bursts (RSP) of type II, interpreted as the signature of shock wave initiation in the solar corona, and Type IV, representing upward/moving material in corona. This procedure is justified by the fact that the growing observations support the point that flares and CME are two phenomena in one process. The neural network was used to construct this scheme enabling to determine the probability, with which flares will be followed by a geomagnetic response of particular intensity. The successfulness of forecasts produced after the fact depended on the flare class and on the combination of radioburst types. In the case of RSP IV, 58% of the geomagnetic responses of X-ray flares of at least B class were successful. If only RSP II was observed, the forecast was successful only for flares of the X class (67% of successful forecasts). In the second step, a strong geomagnetic response was correctly forecast after geoeffective flares in 58% of the cases. The results are in good agreement wit recent papers based on physical modeling.

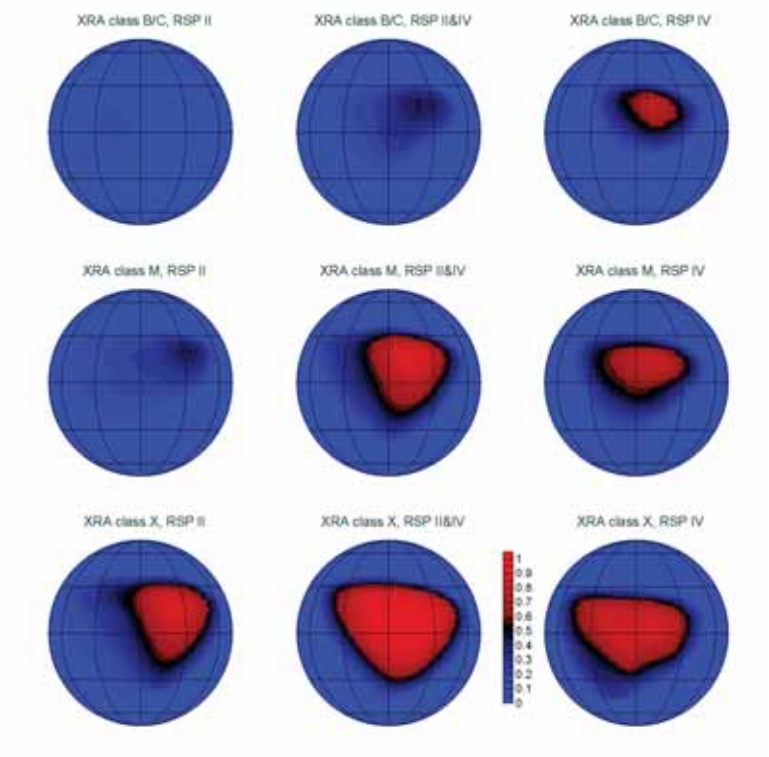


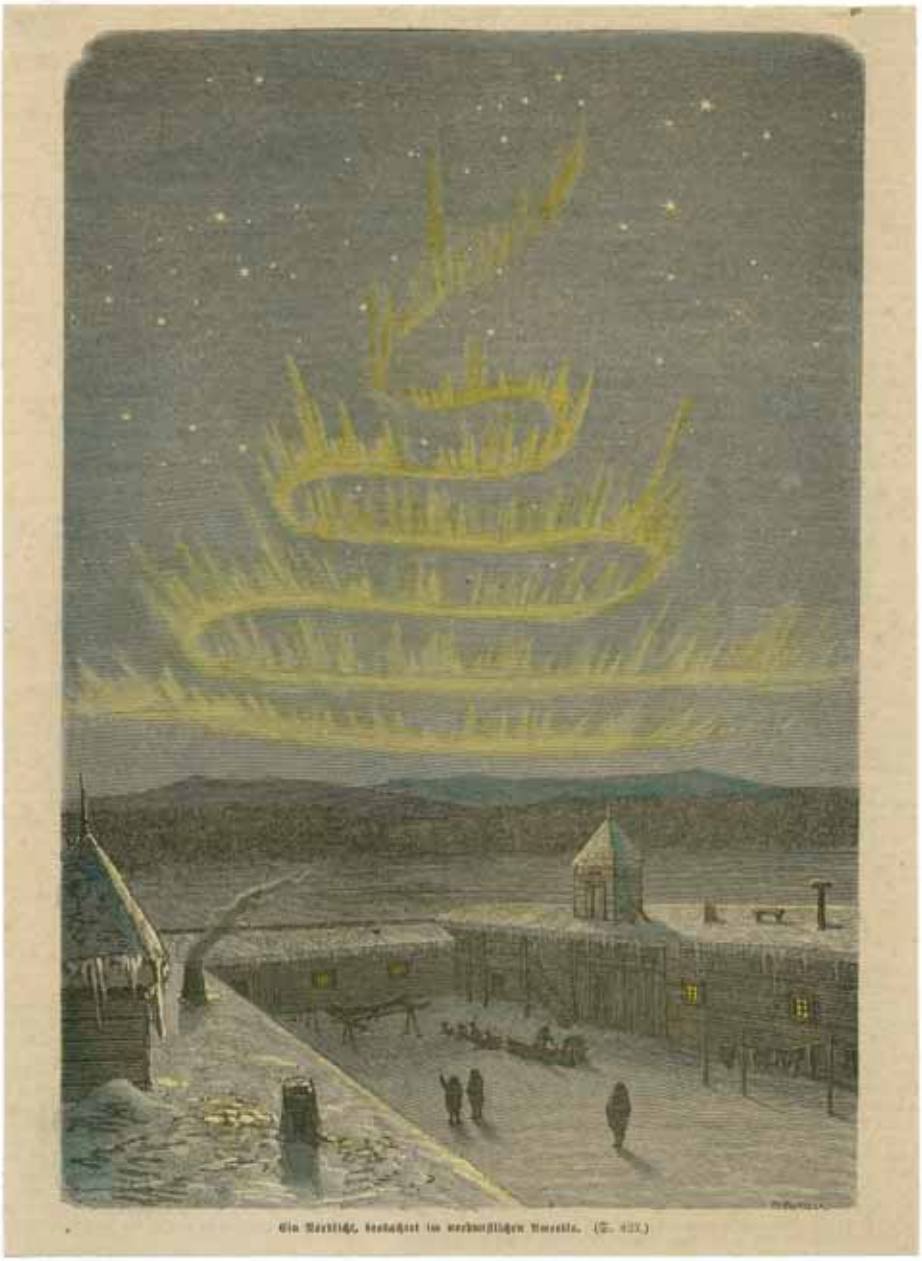
Figure 1

Distribution of areas of geoeffective X-ray flares on the solar disc. The areas in which the probability of flare geoeffectiveness is higher than 50% are shown in red.

References

Bochníček, J., Hejda, P., Valach, F., 2007. Solar energetic events in the years 1996-2004. The analysis of their geoeffectiveness*. Stud. Geophys. Geod., 51, 439-447.*

Valach, F., Hejda, P., Bochníček, J., 2007. Geoeffectiveness of XRA events associated with RSP II and/or RSP IV estimated using the artificial neural network*. Stud. Geophys. Geod., 51, 551-562.*



Northern lights (aurora) observed in western North America. Hand-coloured xylograph, illustration from the journal Neue Illustrierte Zeitung, Vienna, 1880. Private collection, Prague.

Observatories and mobile data acquisition systems

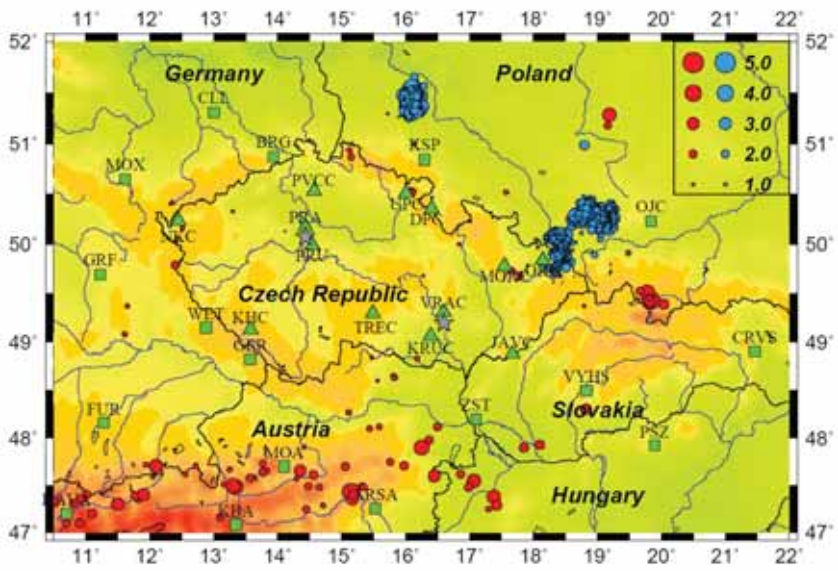
A significant part of the Institute's mission involves acquisition and sharing of primary geophysical data through a number of observatories and mobile measuring equipment. More information, including technical details and geographic coordinates of the Institute's observatories, can be found at http://www.ig.cas.cz/en/structure/observatories/.

Czech Regional Seismic Network (CRSN)

Seismological observations of the Institute of Geophysics have a long tradition and form a fundamental part of its research. Numerous projects have utilized the data provided by the Institute's observatories. In 2006-2007, the Institute of Geophysics operated seven stations of the CRSN: Průhonice ("PRU" in Fig. 1, since 1957), Kašperské Hory (KHC, since 1961), Dobruška/Polom (DPC, since 1992), Nový Kostel (NKC, since 1997), Úpice (UPC, since 1987), Panská Ves (PVCC, since 2003), Třešť (TREC, since 2005). Digital data from all stations are transferred to the Institute in real time through the Internet. Software packages Antelope and SeisComP are used for automated data acquisition and exchange. The Institute of Geophysics is strongly involved in international data exchange with global data centers and a number of European national data centers and observatories. The virtual network of the Institute consists at present of about 60 real-time seismological stations in central and southern Europe. About 20 new stations were added to the virtual network in 2006-2007, as a result of broad international cooperation of the Institute of Geophysics established in the frame of EC project Meredian (2000-2005).

Figure 1

Stations of the Czech Regional Seismic Network (green triangles) and regional seismic events in central Europe for the period 2006-2007. Tectonic earthquakes are depicted as red circles, mining-induced shocks as blue circles. The size of the circles is proportional to the earthquake magnitude.



Seismological Data Center of the Institute of Geophysics provides the following services:

- Automated, near-real time data acquisition of continuous broadband and short-period seismic data by Antelope and SeedLink software packages;
- Global data exchange of both seismic phase readings and digital records with major international data centers (ISC, NEIC, IRIS, ORFEUS, EMSC) and a number of neighbouring observatories;

– Daily analysis of digital seismograms by Unix program Seismic Handler. Rapid location of strong seismic events in Central Europe by program LocSat;
– Archiving of digital records: continuous records are stored on a large raid system and archived on a tape robot device;
– Compiling and publishing seismological catalogues and bulletins on the web, collection and evaluation of macroseismic reports about earthquakes felt on the territory of the Czech Republic;
– Recent automated locations of the CRSN and live seismograms of selected stations are displayed on the web pages of the Institute;
– Informing the public through TV and radio interviews and articles in press about prominent strong earthquakes and strong regional events;

Geothermal climate-change observatories

The geothermal climate-change observatories on the campus of the Institute of Geophysics at Spořilov, at the meteorological station Kocelovice (operated by the Czech Hydrometeorological Institute) and near Potůčky (Krušné Hory Mountains) were established in the years 1993, 1998 and 2002, respectively. The observatories monitor air, soil and bedrock temperatures at a sampling rate of 30 minutes with the aim to provide data on the air-ground temperature coupling and on a propagation of seasonal, interannual and secular surface temperature changes into the bedrock. The monitoring is expected to continue into the future, to map the tracking of the air and ground mean annual temperatures on an interannual time scale. The tracking is crucial for the proper climatic interpretation of the ground surface temperature history reconstructed from borehole temperature profiles.

The influence of vegetation cover on the soil temperatures is studied systematically using data from the fourth observatory located on the premises of the Institute of Geophysics in Prague - Spořilov. The monitoring system launched in 2002 provides data on the soil temperatures to the depth of 0.5 m under different surface conditions, namely under grass, barren soil, sand, and asphalt. The system was upgraded by installation of one pyranometer for monitoring the incoming short-wave radiation and four pyranometers for the short-wave radiation reflected by the individual surfaces. The monitoring provides data for a detailed study of the mean annual difference between air and soil temperatures, its long-term stability and dependence on the vegetation cover and provides useful data for an array of other disciplines like agronomy, forestry, ecological studies or alternative energy sources.

See pp. 26–28 for the most recent research using the data from these observatories.

Figure 2
Air-ground temperature monitoring on the campus of Institute of Geophysics at Prague – Spořilov.

Geomagnetic observatory

The long tradition of geomagnetic observations in Prague dates back to 1839. Due to the increasing influence of urban magnetic noise since the beginning of the 20th century, the Prague observatory was closed down in 1926, and was replaced in 1946 by the Průhonice observatory near Prague. Rapid expansion of the city and construction of DC - powered railways resulted in a deterioration of this location. In 1967, the observatory was moved to Budkov near Prachatice in south Bohemia, a sparsely populated area. Currently the observatory is equipped with two digital systems. CANMOS, installed in 1992 in co-operation with the Geomagnetic Observatory of the Geological Survey of Canada consists of a triaxial Narod S-100 ring-core magnetometer, an ELSEC 820 PPM magnetometer, and a control unit based on MS-DOS operating system. The main parts of GDAS system are DMI suspended fluxgate magnetometer, Overhauser proton magnetometer and Pentium-type embedded PC with QNX4 operating system and SDAS data acquisition software developed by British Geological Survey. Absolute measurements are carried out by DI magnetometer (fluxgate sensor mounted on non-magnetic theodolite Zeiss 010B). The data are transmitted via telephone network to the Institute of Geophysics in Prague. They are stored and processed on the network server and one-minute values of three components of the magnetic field are transmitted via e-mail to the Geomagnetic Information Node (GIN) in Edinburgh, U.K. Yearly collections of definitive data are published on the INTERMAGNET CD-ROM. The Geomagnetic Department has been issuing daily forecasts of geomagnetic activity for Central Europe since 1994, weekly forecasts since 1995. Since 1998 the short term forecasts have been sent to Czech TV, where they are presented as part of the Weather Forecast and displayed on the teletext. At present, the forecasts, as well as reports of the actual state of the geomagnetic field in our region, are presented on the web pages of the Regional Warning Centre Prague (http://rwcprague.ufa.cas.cz/).

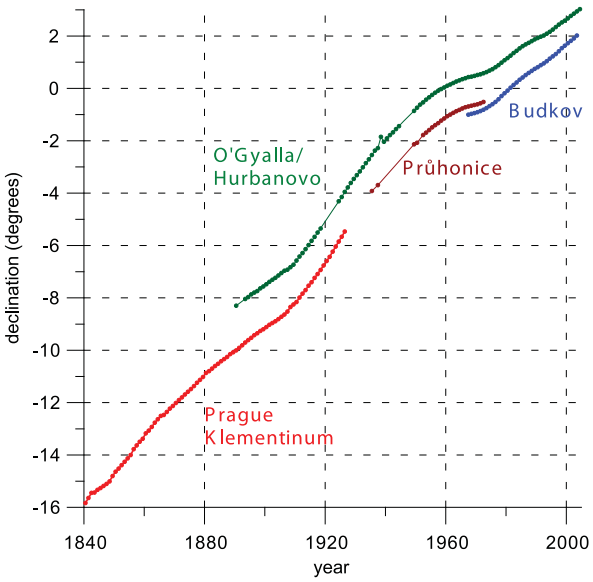


Figure 3

Magnetic declination measured at Prague-Klementinum, Průhonice and Budkov observatories. Data from Observatory Hurbanovo (South Slovakia) are given for comparison.

MOBNET, a portable network of three-component seismographs and digital acquisition systems

The Institute of Geophysics owns a set of mobile seismic stations, deployed according to operative decisions in different research projects. This set consists of 32 short-period Le3D seismographs, 15 broad-band STS2 seismographs, and 55 GAIA acquisition systems. The GAIA recording instrumentation is fully compatible as regards built-in software and output data formats. Processing of seismic data is then easy and data follow strictly all required standards.

Stations of the pool participated in several passive experiments. Ten BB stations finished three year operation in the Northern Apennines in October 2006 within the project RETREAT

2002-2007 (Plomerová et al., 2006; Margheriti et al., 2006; Salimbeni et al., 2007). Stations were newly installed within the project PASSEQ, which focuses on the upper mantle structure beneath an elongated array running from Bavaria, through western part of the Bohemian Massif (Eger Rift) to Lithuania. Stations of the pool are deployed both on territory of the Czech Republic and in Poland. The stations were also included in experiment BOHEMA III

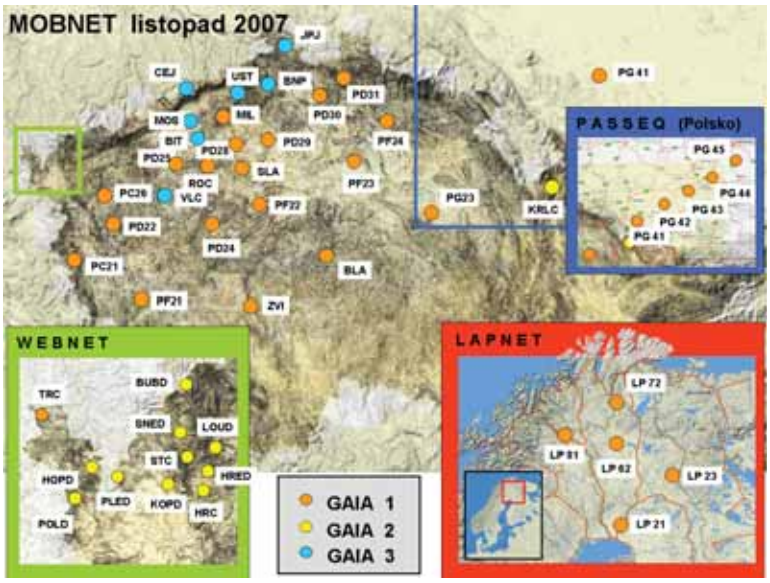


Figure 4

Map showing the distribution of MOBNET stations near the end of 2007.

(2005-2006) covering the southern part of the Bohemian Massif. A subset of data recorded by the array will complement data of the experiment ALPASS (Austria),which covered a region south of the Bohemian Massif.

Nine GAIA stations are installed in the West Bohemia seismoactive region as a part of the WEBNET network. Together with other 13 permanent seismic stations of WEBNET the total number reaches 22 stations thus ensuring both precise localization of local earthquakes and determination of the focal mechanism. In case of increased seismic activity the WEBNET network can be complemented by other MOBNET stations.

Current publications utilizing data collected with the MOBNET network include the following:

Plomerová, J., Margheriti, L., Park, J., Babuška, V., Pondrelli, S., Vecsey, L., Piccinini, D., Levin, V., Baccheschi, P., and Salimbeni, S., 2006. Seismic Anisotropy beneath the Northern Apennines (Italy): Mantle Flow or Lithosphere Fabric? *Earth Planet. Sci. Lett., 247: 157-170.*

Margheriti, L., Pondrelli, S., Piccinini, D., Piana Agostinetti, N., Lucente, F. P., Amato, A., Baccheschi, P., Giovani, L., Salimbeni, S., Park, J., Brandon, M., Levin, V., Plomerová, J., Jedlička, P., Vecsey, L., Babuška, V., Fiaschi, A., Carpani, B. and Ulbricht, P., 2006. Retreat seismic deployment in the Northern Apennines. Annali di Geofisica, *Annals of Geophysics, 49, N. 4/5.*

Salimbeni, S., Pondrelli, S., Margheriti, L., Levin, V., Park, J., Plomerová, J., Babuška V. Abrupt change in mantle fabric across Northern Apennines detected using seismic anisotropy, 2007. *Geophys. Res. Letters, 34, L07308, doi:10.1029/2007GL029302.*

Plomerová, J., Achauer, U., Babuška, V., Vecsey, L., and BOHEMA working group, 2007. Upper mantle beneath the Eger Rift (Central Europe): plume or asthenosphere upwelling? *Geophys. J. Int., 169, 675-682; doi: 10.1111/j.1365-246X.2007.03361.x*

Babuška, V., Plomerová, J., Fischer, T., 2007. Intraplate seismicity in the western Bohemian Massif (central Europe): a possible correlation with a paleoplate junction*. J. of Geodynamics 44, 149-159, doi:10.1016/j.jog.2007.02.004.*

WEBNET network

West Bohemia/Vogtland earthquake swarm region belongs to the best–monitored seismically active areas in Europe. The WEBNET network, jointly operated by the Institute of Geophysics and the Institute of Rock Structure and Mechanics (IRSM) of the ASCR in Prague, and a smaller network KRASNET, operated by the Institute of the Physics of the Earth of the Masaryk University in Brno, are located in the West Bohemian seismoactive region. Further networks providing relevant, high quality data have been working in NE Bavaria and SE Saxony. WEBNET

includes thirteen broad band three-component digital seismic stations consisting of the SM-3 short-period seismometers and Janus-Trident/ Nanometrics acquisition systems, and covers an area of about 900 km^2. Its configuration and the parameters of the seismograph systems guarantee high-quality recording of West Bohemia/Vogtland events of magnitudes $-0.5 \leq ML \leq 5$ in a frequency range of 0.5 to 80 Hz with a sampling frequency of 250 Hz. Thus, WEBNET makes it possible to record high-frequency waves generated by local events, short-period body waves of regional and distant earthquakes, and surface waves excited by quarry blasts fired in the neighbourhood of the region under study. Data from all stations are transmitted via Internet to Institute of Geophysics, Prague. In addition, a three-component very broad band (VBB) system providing continuous digital records of seismic signals with periods up to 120 seconds has been operating at stations NKC (in the centre of the Nový Kostel zone) and LAC (southern part of the seismoactive region). To provide the best possible area and azimuth coverage with respect to the individual focal zones, ten seismic vaults consisting of a container with a concrete pillar about 2 m below the surface were built in the West Bohemia for deploying mobile stations in the case of enhanced seismic activity. The seismograms of all tectonic events (about 25000), recorded by WEBNET and the VBB stations since, respectively, 1992 and 1998 are archived in a digital database. Data from other networks operating in the region are available on request.

See pp. 14–15 for the most recent research using the data from these observatories.

Gravity and Earth tides observatories

The observatory Jezeři was established in 1982 when a complex investigation of the slopes of the Krušné hory Mountains began, with the aim of controlling the stability of the slopes of an adjacent open-cast brown coal mine. The observatory consists of two tiltmeter sites with permanent recordings of tilts in a horizontal gallery. Station 1 is located at the depth of 410 m in the mountain crystalline massif, and has been operating since 1982. Its aim is to record the stability of this deep block of the massif suspected of rotation or sliding movements. Station 2 was set up in 2001 in order to monitor the weak zone of the crystalline basement close to the contact with Tertiary sediments containing a coal seam. This station is a part of a fast geomechanic monitoring system of the mining company. It has clearly recorded, e.g., the effect of precipitation during the 2002 floods on the block stability, on anomalous tilts caused by water saturation. This observatory has been technically upgraded for automatic data transmittion and nowadays is being prepared for real-time monitoring. The aim of the system is to provide real-time continuous information on the stability of the mine slopes suspected of possible sliding. Day-to-day evaluation of the data, together with all other observed parameters, should provide indications of slope instability and warning signals for the mine authorities. At the same time, the data are a subject to long-term earth tide effects investigation. The new observatory Skalná is located in the West Bohemia seismoactive region in an underground gallery built in a granite block in the town of Skalná. The observatory should contribute to the monitoring of the ongoing geodynamic processes. It is furnished with a couple of tiltmeters, a seismograph, a barometer and a special deformation meter. Except the seismograph, the other equipment is still in a testing period, mainly due to stabilisation of the tiltmeters in local temperature conditions and their stable setup on the rock. Ocassionally, continuous measurements of gravity are performed to test local changes of the gravity field. A significant signal was recorded during the Sumatra earthquake in Dec. 2004, when the trend of the gravity variations changed for a long time.

See pp. 14–15 for the most recent research using the data from these observatories.

International Publications

The following list contains scientific publications authored or co-authored by employees of the Institute of Geophysics (underlined in the reference heading), only in journals with the ISI Impact Factor. A complete list of all publications is available at http://www.ig.cas.cz/en/research-&-teaching/publications/, and on the homepages of individual researchers.

2006

Babuška, V. - Plomerová, J.
European mantle lithosphere assembled from rigid microplates with inherited seismic anisotropy.
Physics of the Earth and Planetary Interiors, 158, 2-4 (2006), 264-280.

Bochníček, J. - Hejda, P.
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Studia geophysica et geodaetica, 50, 2 (2006), 299-318.

Čermák, V. - Šafanda, J. - Bodri, L. - Yamano, M. - Gordeev, E.
A comparative study of geothermal and meteorological records of climate change in Kamchatka.
Studia geophysica et geodaetica, 50, 4 (2006), 675-695.

Červený, V. - Pšenčík, I.
Trajektoriji smeščenija častic v ploskich volnach v vjazkouprugoj anizotropnoj srede.
Geologija i geofizika, 47, 5 (2006), 557-567.

Červený, V. - Pšenčík, I.
Particle motion of plane waves in viscoelastic anisotropic media.
Russian Geology and Geophysics, 47, 5 (2006), 551-562.

Červený, V. - Pšenčík, I.
Energy flux in viscoelastic anisotropic media.
Geophysical Journal International, 166, 3 (2006), 1299-1317.

Fialová, H. - Maier, G. - Petrovský, E. - Kapička, A. - Boyko, T. - Scholger, R.
Magnetic properties of soils from sites with different geological and environmental settings.
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Journal of Applied Geophysics, 59, 4 (2006), 273-283.

Fischer, T. - Kalenda, P. - Skalský, L.
Weak tidal correlation of NW-Bohemia/Vogtland earthquake swarms.
Tectonophysics, 424, 3-4 (2006), 259-269.

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Kapička, A. - Hrouda, F. - Petrovský, E. - Poláček, J.
Effect of plastic deformation in laboratory conditions on magnetic anisotropy of sedimentary rocks.
High Pressure Research, 26, 4 (2006), 549-553.

Knab, M. - Hoffmann, V. - Petrovský, E. - Kapička, A. - Jordanova, N. - Appel, E.
Surveying the anthropogenic impact of the Moldau river sediments and nearby soils using magnetic susceptibility.
Environmental Geology, 49, 4 (2006), 527-535.

Kozák, J. - Vaněk, J.
The 1855 Visp (Switzerland) earthquake: early attempts of earthquake intensity classification.
Studia geophysica et geodaetica, 50, 1 (2006), 147-160.

Kozák, J.
San Francisco earthquake of April 18th, 1906, a hundred-year anniversary of disastrous Californian event.
Studia geophysica et geodaetica, 50, 2 (2006), 319-321.

Kratinová, Z. - Závada, P. - Hrouda, F. - Schulmann, K.
Non-scaled analogue modelling of AMS development during viscous flow: a simulation on diapir-like structures.
Tectonophysics, 418, 1-2 (2006), 51-61.

Magiera, T. - Strzyszcz, Z. - Kapička, A. - Petrovský, E.
Discrimination of lithogenic and anthropogenic influences on topsoil magnetic susceptibility in Central Europe.
Geoderma, 130, 3-4 (2006), 299-311.

Margheriti, L. - Pondrelli, - Piccinini, D. - Agostineti, N. P. - Giovani, L. - Salimbeni, - Lucente, F. P. - Amato, A. - Baccheschi, P. - Park, J. - Brandon, M. - Levin, V. - Plomerová, J. - Jedlička, P. - Vecsey, L. - Babuška, V. - Fiaschi, A. - Carpani, B. - Ulbricht, P.
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On determination of the Curie point from thermomagnetic curves.
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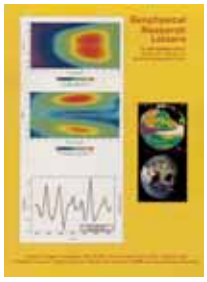
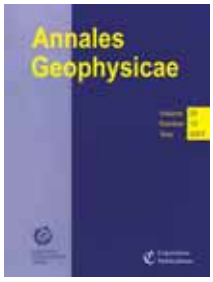
Plomerová, J. - Margheriti, L. - Park, J. - Babuška, V. - Pondrelli, - Vecsey, L. - Piccinini, D. - Levin, V. - Baccheschi, P. - Salimbeni, S.
Seismic anisotropy beneath the Northern Apennines (Italy): Mantle flow or lithosphere fabric?.
Earth and Planetary Science Letters, 247, 1-2 (2006), 157-170.



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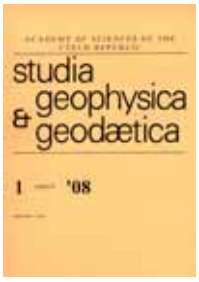

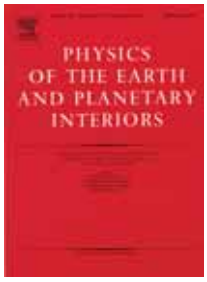

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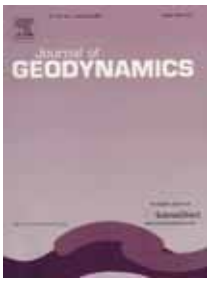

List of supported research projects running in 2006-2007

— Compiled from the data of CEP database (Central Register of Projects, see http://aplikace.isvav.cvut.cz/prepareProjectForm.do)

Funding bodies:

— GAASCR = Grant Agency of the ASCR, GACR = Czech Science Foundation,

— MEYS = Ministry of Education Youth and Sports, MEnv = Ministry of Environment

— MIT = Ministry of Industry and Trade

Project ID	Project Title	Funding	Responsible Investigator	Duration
IAA300120704	Numerical models of the hydromagnetic processes and geodynamo in the Earth's core	GAASCR	Ján Šimkanin	2007-2011
IAA300120709	Mantle lithosphere of north-central Europe – mosaic of micro-continents	GAASCR	Jaroslava Plomerová	2007-2011
GA205/07/1088	Eger Rift - deep lithosphere structure, its origin and geodynamic development	GACR	Vladislav Babuška	2007-2011
SP/2E1/153/07	The "water/rock/landscape" system interaction principles and its application in groundwater protection in the Czech Republic	MEnv	David Uličný	2007-2011
IAA300120701	Long-term monitoring and analysis of dynamics of atmospherically deposited magnetic particles in soils	GAASCR	Aleš Kapička	2007-2010
IAA300120603	Long term measurement and analysis of soil temperature below different surfaces	GAASCR	Jan Šafanda	2006-2010
IAA300460602	Model of the upper crust in the Eger Rift and surroundings	GAASCR	Miroslav Novotný	2006-2010
IAA300120608	Short term and long term variations of the geomagnetic field: data analyses and forecasts	GAASCR	Pavel Hejda	2006-2010
IAA300120703	Effects of external inhomogeneous sources on the electromagnetic field of the Earth within the Central and Northeast Europe	GAASCR	Světlana Kováčiková	2007-2010
GA205/07/0292	Basic geoelectrical units at the eastern margin of Bohemian Massif and its contact with Carpathians by means of magnetoteluric sounding	GACR	Václav Červ	2007-2010
GA205/07/0941	Application of soil magnetometry for pollution mapping in regional scale (Ore Mts. Region)	GACR	Aleš Kapička	2007-2009
IAA200120701	A new optimizing algorithm ANNO and typical geophysical inverse problems	GAASCR	Bohuslav Růžek	2007-2009
IAA300120606	Magnetic properties of particles from solid atmospheric deposits and their relation to the environmental pollution	GAASCR	Eduard Petrovský	2006-2009
IAA300120706	Amplitude modulation of hemipelagic cycles: a new tool for analysis of depositional distortion of climate signal	GAASCR	Jiří Laurin	2007-2009
1QS300120506	Development of methods for cosmic weather forecasting and the consequences for the system ionosphere-atmosphere	ASCR	Josef Bochníček	2005-2009
1QS300460551	Definition of geodynamic mobile zones on the Earth's surface and their assessment for applications in land planning and construction designing	ASCR	Zuzana Jechumtálová	2005-2009
KJB300120702	Fabric patterns of granite diapirs in static and dynamic conditions: integrated analogue, field and numerical approaches	GAASCR	Zuzana Kratinová	2007-2009

IAA300120609	Interactions between water-mass circulation, hydrodynamic conditions of sedimentation, and relative sea-level changes in an epeiric seaway: the Bohemian Cretaceous Basin, Central Europe	GAASCR	David Uličný	2006-2008
KJB300120604	Identification and a characterization of ultra-fine superparamagnetic particles in soils	GAASCR	Hana Fialová	2006-2008
GA205/06/1181	Temporal variations of the susurface temperature in the structure Chicxulub	GACR	Jan Šafanda	2006-2008
IAA300120502	Earthquake focus of finite extent from higher order moment tensors: resolving power with inaccurate model parameterization	GAASCR	Jan Šílený	2005-2008
IAA3012405	Mechanisms causing generation of anisotropic domains in the mantle litosphere of continents	GAASCR	Jaroslava Plomerová	2004-2008
GA205/06/1780	Earthquake swarms in western part of the Bohemian Massif and the correspondence with the core fluids	GACR	Josef Horálek	2006-2008
GA205/06/1823	Record of tectonic processes and sea level changes in the initial stage of intracontinental basin formation: cenomanian of the Czech cretaceous basin	GACR	Lenka Špičáková	2006-2008
KJB300120605	Shear wave splitting – generalization of the method to direct S waves and its applications	GAASCR	Luděk Vecsey	2006-2008
GA205/06/0557	Elektromagnetic induction and conductance distribution in the earth's interior: global continental and regional 3-D inhomogeneous models	GACR	Oldřich Praus	2006-2008
KJB300120601	3D modeling of anthropogenic influence to the temperature field below the surface	GAASCR	Petr Dědeček	2006-2008
KJB301110703	Fabric development during emplacement of volcanic bodies and their dynamics of cooling and fracture formation studied by means of analogue and mathematical modeling	GAASCR	Prokop Závada	2007-2008
GA203/05/2256	Magnetic stimuli-responsive hydrophilic polymer microspheres for biomedicine/bioengineering	GACR	Eduard Petrovský	2005-2007
1P05LA256	Activities in the frame of IAGA (International association for geomagnetism and aeronomy)	MEYS	Eduard Petrovský	2005-2007
GA205/05/2182	Seismic waves in viscoelastic anisotropic media	GACR	Ivan Pšenčík	2005-2007
IAA3012308	Kinematic and dynamic events as indicators of seismo-tectonic activity in western Bohemia	GAASCR	Jan Mrlina	2003-2007
2A-1TP1/043	Drilling geothermal prospection for energy exploitation of Litoměřice structure	MIT	Jan Šafanda	2006-2007
IAA3042401	Dependencies between solar and geomagnetic activities and the tropospheric circulation of the northern hemisphere	GAASCR	Josef Bochníček	2004-2007
IAA3012401	Electromagnetic fields in the inhomogeneous and anisotropic Earth	GAASCR	Josef Pek	2004-2007
1P05OC031	Daily forecasts of the geomagnetic activity for medium altitudes	MEYS	Pavel Hejda	2005-2007
KJB300120504	Non-shear mechanisms of strong earthquakes determined from teleseismic recordings	GAASCR	Zuzana Jechumtálová	2005-2007
IAA3012303	Distribution of seismic activity as an indicator of volcanic sources at convergent margins of the litospheric plates	GAASCR	Aleš Špičák	2003-2006
LA 150	International continental deep borehole drilling program	MEYS	Aleš Špičák	2002-2006
GP205/04/P182	Modeling the generation of the geomagnetic field by hydromagnetic dynamo	GACR	Ján Šimkanin	2004-2006
GA205/04/0746	Stochastic interpretation of geoelectricity induction data	GACR	Josef Pek	2004-2006
GA205/04/0740	EMTESZ/CEMES: Deep conductivity model of the Transeuropean suture	GACR	Václav Červ	2004-2006
IAA3012309	Seismic waves and seismic sources in anisotropic media	GAASCR	Václav Vavryčuk	2003-2006
GA205/04/0748	Boundaries between anisotropic blocks of mantle litosphere mapped using data from passive seismic experiments and their relation to the crustal tectonics	GACR	Vladislav Babuška	2004-2006

Studia Geophysica et Geodaetica

Studia Geophysica et Geodaetica (SGG), published by Institute of Geophysics since 1956, is an international scientific journal covering all aspects of geophysics, geodesy, meteorology and climatology. The recent Editorial Board, established in 2000, has been striving for steady improvement of the journal quality and broadening the international range of authors and readers. Distribution of SGG authors in 2006 is shown in Fig.1. Currently, 22 experts from 11 countries serve as editors (see list below). Electronic and printed versions of the journal are distributed by Springer.

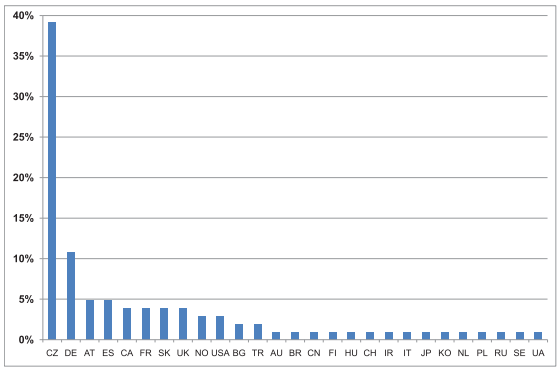

Figure 1

Distribution of SGG authors by country of their affiliation, in 2006.

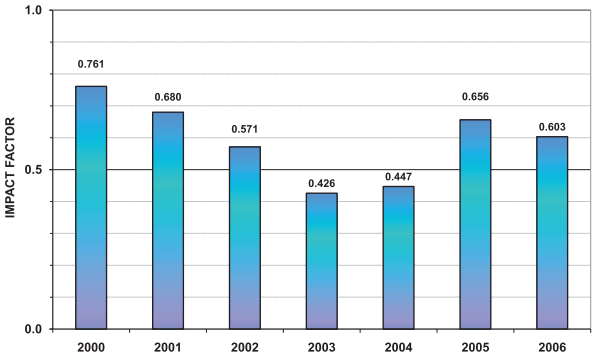

Figure 2

Impact factor of Studia Geophysica et Geodaetica between 2000 and 2006.

At present, the journal publishes between 40 and 50 original, reviewed papers per year. The mean submission to acceptance time is about 6 months. Rejection rate is slightly over 30% of original submissions. Special issues are published on various occasions, commonly from scientific meetings. In the years 2006 and 2007, two special issues containing selected contributions presented at the workshop „Seismic waves in laterally inhomogeneous media VI" Hrubá Skála, Czech Republic, June 20-25, 2005 were published (issues 3/2006 and 1/2007).

Since January 2002, the journal has been included again into the Scientific Citation Index list. The Impact Factor for the period 2000-2006 is shown in Fig.2, see also the ISI Journal Citations Report (www.jcrweb.com). The journal is abstracted or indexed in Current Contents: Physical, Chemical and Earth Sciences; ISI Alerting Services; Meteorol. and Geoastrophys. Abstracts and Elsevier/Geo Abstracts. At present, the journal is ranking as 11th among the total of 22 journals with Impact Factor published in the Czech Republic.

Lists of articles can be viewed and, with subscription, full text files downloaded via the following web page: http://www.ig.cas.cz/en/studia-g&g/

The most cited paper in the journal history:
V. Jelínek, 1978. Statistical processing of anisotropy of magnetic susceptibility measured on groups of specimens. Stud.geophys.geod., 22, 50-62, (206 citations by October 2007).

Editorial Board of Studia Geophysica et Geodaetica, 2007

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International research collaboration

The EU Project IMAGES (Induced Microseismics Applications from Global Earthquake Studies)

The project develops a „Transfer of Knowledge Industry-Academia Partnership" (TOK-IAP) between Schlumberger Cambridge Research, Cambridge, UK (industrial partner) and the Institute of Geophysics, the Charles University in Prague, the Potsdam University, the Institute of Physics of the Earth in Paris and the Berlin University (academic partners). It is a 6th Framework Programme contract No. MTKI-CT-2004-517242.

The project benefits petroleum industry by developing tools and techniques for seismic monitoring of gas and oil reservoirs (hydraulic fracture monitoring and passive seismic) to control rock fracturing, optimize the reservoir production, prolong life of existing reservoirs, and mitigate hazard associated with the occurrence of induced microearthquakes. The seismic monitoring helps to solve geomechanical problems in petroleum industry, such as imaging deformations associated with primary production, secondary recovery or waste injection operations. Earthquake seismology benefits from the project by having an access to high-quality data of seismicity in reservoirs and a unique opportunity: (1) to study fluid-driven seismicity, in particular, rock-fluid interactions and the role of pore-fluid pressure in seismicity pattern and in triggering of earthquakes by fluid flow, and (2) to inspect rupture processes in a field scale and under controlled conditions. The project is supervised by Prof. F. Cornet who presently coordinates research in the Corinth Rift Laboratory and has an extensive experience with large-scale academic EU projects in passive seismic and hydraulic fracture monitoring.

The Institute of Geophysics researchers involved: V. Vavryčuk (leader of the IG team), A. Boušková, T. Fischer, Z. Jechumtálová, I. Pšenčík, J. Šílený.

Selected other projects with active involvement of researchers from the Institute of Geophysics in 2006-2007:

INTAS, Ref. Nr 03-51-5807 „Long-term magnetohydrodynamics of the Earth, planets and moons" (2004-2007); I.G. researchers involved: P. Hejda, J. Šimkanin;

— Consortium SW3D „Seismic waves in complex 3D structures". Consortium members: BP Exploration and Production Inc., Chevron Texaco, ExxonMobil Upstream Res.Co., Petrobrás - CENPES, Schlumberger Cambridge Res. Ltd., Shell International Exploration and Production B.V. I.G. researchers involved: I. Pšenčík, V. Vavryčuk, J.Šílený;

— Projekt CNPq (National Council for Scientific and Technological Development, Brazil) „Extensao de metodos de refinamento do modelo de velocidade para meios anisotropicos. Participating institutions: UNICAMP Campinas, UFPa Belém, Brazil. I.G. researchers involved: I.Pšenčík;

— RETREAT: 2002-2007 a part of the Continental Dynamics programme of the NSF (USA). http://earth.geology.yale.edu/RETREAT/ ; I.G. researchers involved: J. Plomerová;

— PASSEQ 2006-2008 (Passive Seismic Experiment in the TESZ). I.G. researchers involved: J. Plomerová;

— COST724 „Developing the scientific basis for monitoring, modelling and predicting Space Weather" (2004-2007), IG researchers involved: J. Bochníček, P. Hejda.

Professional events

— In 2006 and 2007, research groups at the Institute of Geophysics organized or took part in organizing a number of professional meetings. A complete overview, with supplementary materials for each event, is posted on http://www.ig.cas.cz/en/about-us/conferences/.

10th Symposium on Study of the Earth's Deep Interior (SEDI), Prague, Czech Republic, July 9-14, 2006

— The 10th Symposium on Study of the Earth's Deep Interior (SEDI), organized by the Institute of Geophysics of the Academy of Sciences, was held in the Congress Centre of the Czech University of Agriculture, Prague, with 158 participants from 14 countries. Jonathan Aurnou gave the Zatman lecture, and Julien Aubert, Keith Koper, and Jonathan Mound won Doornbos prizes for outstanding research on the deep Earth by a young scientist. The program consisted of eight topical half-day sessions that covered, in an interdisciplinary manner, the following topics: structure and chemistry of the core and lower mantle, core-mantle interactions, the geodynamo and core dynamics and thermodynamics, layer D" and mantle convection, and the interiors of other bodies in the solar system. All oral presentations were on invitation only. A plenary discussion was led by the members of International Program Committee or other prominent scientists selected by them in advance. A detailed report on the symposium presented in the Deep Earth Dialog, Number 14, can be found at http://www.sedigroup.org.

6th „Castle Meeting" on Heat Flow and the Structure of the Lithosphere, Courtyard Býkov, June 5-10, 2006

— Department of Geothermics of the Institute of Geophysics organized its 6th International Workshop „Heat Flow and the Structure of the Lithosphere" at Býkov Castle Farm near Plzeň, June 5-10, 2006. The meeting was held under the auspices of the International Heat Flow Commission of the IASPEI and was co-sponsored by the Academy of Sciences the Czech Republic. The workshop was attended by 66 participants from 21 countries, and as such represented the largest gathering of the present world heat flow community likely ever.

— The scientific programme of the workshop centered on four major topics: (1) Heat

flow on continents and ocean; (2) Thermal measurements; (3) Geothermics of climate change; and (4) Heat and fluids. One of the evenings was devoted to the business meeting of the International Heat Flow Commission. At present, two special journal issues of the International Journal of Earth Sciences are under the preparation, based on the presentations delivered during the Býkov meeting, one covering basic heat flow problems in crustal and upper mantle structure studies, the other focusing on the borehole climatology. More information can be found on: http://rebel.ig.cas.cz/activities/heat2006-main.html

Other significant events in 2006-7 include the following:

- Workshop / Meeting on Seismic Anisotropy and Geodynamics of The Lithosphere-Asthenosphere System: Třešť, June 17-21, 2006;
- 10th Castle Meeting Paleo, Rock and Environmental Magnetism: Castle of Valtice, 3–8 September 2006;
- 22nd Colloquium „Electromagnetic Depth Research": Hotel Maxičky, Děčín, Czech Republic,October 1-5, 2007;
- 8th West-Bohemia / Vogtland international workshop „Geodynamics of Swarm Earthquake Areas": Františkovy Lázně, October 16 – 19, 2007;

See http://www.ig.cas.cz/en/about-us/conferences/ for a complete list and more details.

Participants of the 6th "Castle Meeting" on Heat Flow and the Structure of the Lithosphere, in front of the Býkov courtyard

Public Outreach Activities

The Institute takes part in the annual „Science and Technology Weeks" organized by the Academy of Sciences. These outreach activities are organized in close connection with the European Science & Technology Week, and aim to inform the general public about the impact of science on daily life and its benefits (http://cordis.europa.eu/scienceweek/home.htm).

The 7th Science and Technology Week, in 2007, had the title „Fascination by Light". The Institute of Geophysics regularly contributes to these activities by its Open Days, usually in November. The visitors can create their own earthquake, learn about the origin and effects of volcanism, take a tour through the Institute's Geopark, or watch a sandbox experiment simulating the building

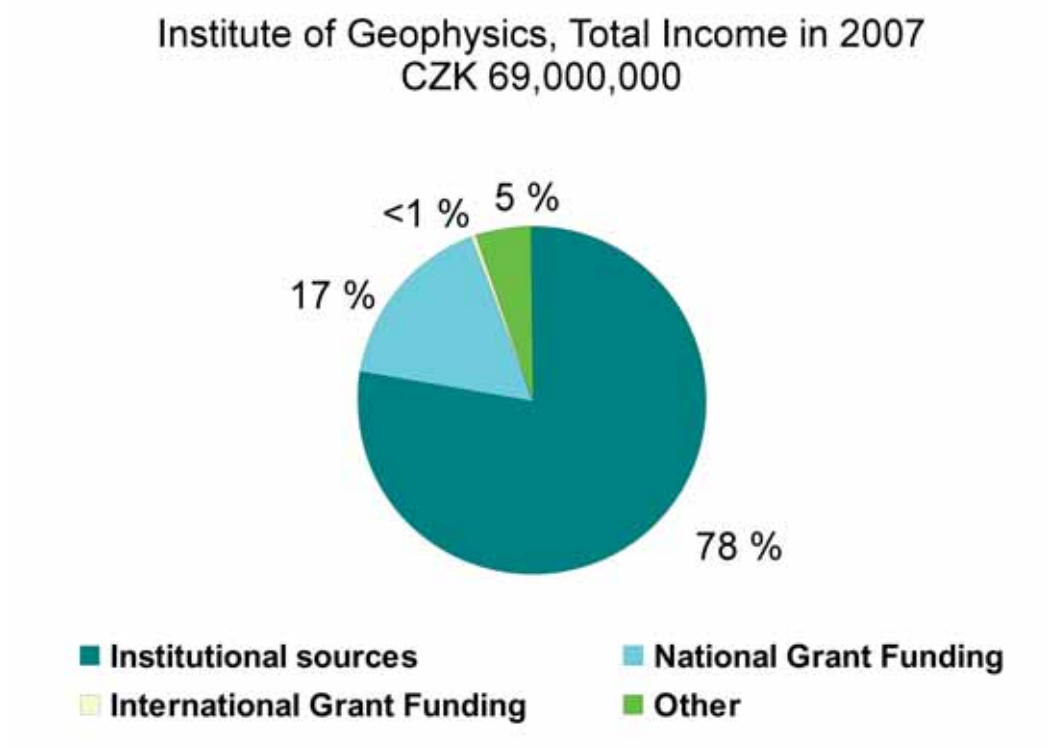
of a mountain range. In 2007, 167 people visited the Institute during the Open Days. Other outreach activities include the project „Science in the streets" in which the Institute participated in 2006 in Prague and Plzeň, or collaboration on the Open Science project: http://www.otevrena-veda.cz/ov/index.php?site=gfu. Apart from the above activities, researchers from the Institute commonly take part in TV and radio broadcasts featuring Earth Science topics. The 100th anniversary of the catastrophic earthquake in San Francisco was commemorated by the exhibition of historical engravings related to the event and other earthquakes, from the collection of Jan Kozák. The exhibition took place in the Academy of Sciences foyer in April-May 2006. The Portuguese edition of the book by J. Kozák, V. Moreira and D. Oldroyd, „Iconografia do Terramoto de Lisboa de 1755" was published by the Academy of Sciences, as a follow-up of the success of the earlier English edition of 2005.

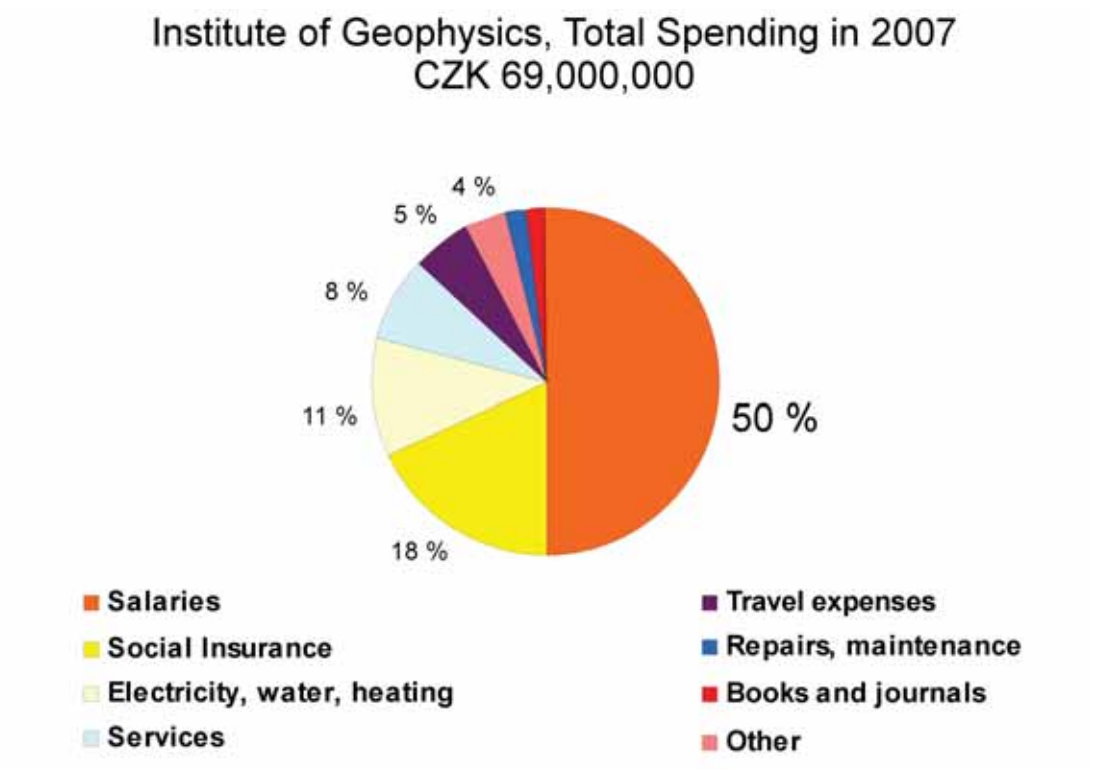
Geopark Spořilov

The GEOPARK of the Institute of Geophysics, open to the public, was built between 2003 and 2007 with generous support from the Prague 4 municipal council and thanks to enthusiasm of companies that donated many rock specimens. The aim of the exhibition is to increase the awareness of the general public about processes operating in the Earth interior and on its surface, and about their products. Currently the Geopark features over 40 large specimens of igneous, sedimentary, and metamorphic rocks from the Bohemian Massif. Explanatory texts and accompanying posters about plate tectonics and the geological history of the Czech Republic are posted in the Geopark and on the Institute's website: http://www.ig.cas.cz/cz/o-nas/popularizace/geopark-sporilov/.

Visitors - locals, casual visitors, and, commonly, schools – can not only appreciate the beauty of the rocks on display or read the posters that accompany the exhibit, but can also play a quiz-game named „The Alchemists' Stone", as an entertaining way to learn about minerals, rocks, and processes that create them.

The Budget of the Institute of Geophysics





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