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The 11th Czech – Polish Workshop
**ON RECENT GEODYNAMICS
OF THE SUDETEN AND ADJACENT AREAS**

ABSTRACTS



Třešť Castle

**Třešť, Czech Republic
November 4-6, 2010**

Organizing Committee of the
11th Czech – Polish Workshop

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OF THE SUDETEN AND ADJACENT AREAS

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ABSTRACTS

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LOW-ANGLE DETACHMENT RELATED TO STRIKE-SLIP FAULTING IN LATE CRETACEOUS MUDSTONES OF THE TABLE MOUNTAINS (SW POLAND)

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Late Cretaceous to Cenozoic low-angle faults in the Sudetes have been sporadically described on the basis of map-scale outcrop patterns and interpreted as thrusts. A well exposed subhorizontal detachment fault that occurs parallel to bedding in Late Cretaceous marly mudstone near to village Jawornica in the Góry Stołowe (in English: *Table Mountains*), is of importance for understanding the style and geometry of Alpine tectonic deformation that took place in end Cretaceous through Cenozoic times. The detachment is exposed in a continuous outcrop, exceeding 1 km in length, along a road cut slope between the Polskie Wrota Pass and the village of Lewin Kłodzki and, most probably, is genetically related to the generally NW-SE trending Mesozoic-Cenozoic **Southern Sudetic Fault System (SSFS)**, within which it occurs. The detachment is exposed in the so called Szczytna Mudstone Member that represents a lithological variety of the middle Turonian (*Inoceramus lamarcki*) Batorów Formation. The rocks affected by deformation are mostly mudstone and calcareous claystone, but locally also limestone (calclutite and clacarenite). The displacement occurred there either on a single fault (Fig. 1a) or on a system of interconnected, kinematically linked faults, generally northwesterly dipping at an angle of up to 20° and parallel or subparallel to the bedding planes of the Cretaceous strata. The shear zone is both at its top and the bottom accompanied by several cm-thick breccia layers of whitish grey colour. The breccia is composed of white calcareous lenses and light grey lithic matrix. It contains numerous microfaults and fractures (Fig. 1). The tectonic setting of the studied outcrops as well as the orientation of the joint sets and the internal structural features of the detachment shear zone seem to support a conjecture that the detachment originated due to thrusting in a local transpressional regime related to the nearby NW-SE trending regional-size strike-slip fault system, SSFS, that was active probably in Latest Cretaceous and during Cenozoic times (Fig. 2).

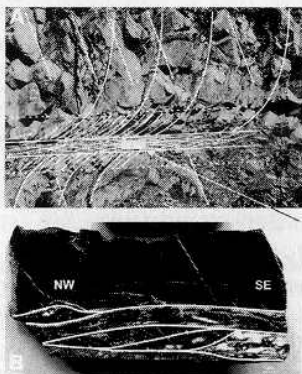


Fig. 1

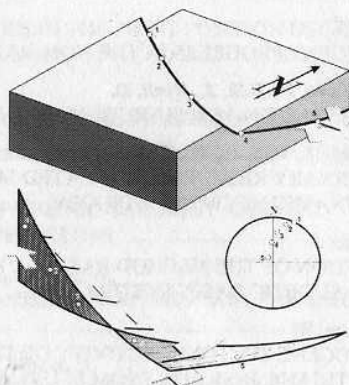


Fig. 2

MONITORING SYSTEM FOR OBSERVATIONS OF ROCK MASS DEFORMATIONS CAUSED BY SUBLEVEL CAVING MINING SYSTEM

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The Kvannevean iron oxide mine in Northern Norway has started to develop a new underground production level in order to continue mining operation. The planned change of mining system from sub-level stoping to sub-level caving (SLC) is connected with removing of protective (crown pillar) pillars below the old Kvannevean open-pit. In the SLC system gradual rock mass deformation on the hanging-wall and footwall sides of the deposit is expected. Whereas uncontrolled caving of rock mass towards the void represents a serious threat to the underground mining operation below the old open-pit. Trial removal of the part of crown pillar in the western part of the deposit has already caused fracturing of the rock mass on the hanging-wall side. With the aim to observe and monitor rock mass deformation process in this area and ensure safe operation of the mine a monitoring system based on periodic total station measurements and a three-tier control-measurement network has been developed for the mine. In the paper the concept of this scheme, results of up-to date field work and guidelines for monitoring has been presented.

This study has been realised within the framework of collaborative research project between the Institute of Mining Engineering of the Wrocław University of Technology (Poland) and the Department of Geology and Mineral Resources Engineering of the Norwegian University of Science and Technology in Trondheim (Norway).

DETERMINATION OF THE SHORT PERIODIC VARIATIONS IN THE GNSS PERMANENT SITES' POSITIONS

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The article is devoted to the analysis of time series of the geodetic coordinates applied for the investigation of the energy at tidal frequencies. The study is based on the permanent GNSS observations processed in short-time intervals which were obtained in the Centre of Applied Geomatics, Military University of Technology. The analysis is based on the time series of geocentric coordinates of the ASG-EUPOS and the associated Slovak and Czech GNSS sites. The Bernese GPS software with implemented Earth's lithosphere tidal deformations model consistent with IERS2003 standards was used. For the tidal ocean loading corrections the FES2004 model was applied. The tidal analysis in the diurnal and semi-diurnal band based on the least squares method confirmed that the model which relies on theoretical tidal

development requires the implementation of additional coefficients. This is particularly important for frequencies which are difficult to be modelled due to coincidence with GPS satellites orbiting, such as K1 and K2 or PS11 relevant to the Free Core Nutation (FCN) effect. At these frequencies the residuals of satellite observations' analyses confirmed existence of the differences that reach several millimetres. The authors also notice the inconsistent behaviour of the phase defined as the time shift between observed and modelled Earth tidal effects. The results of this research form the ideal base for further investigations of spatial distribution of tidal deformational parameters and their correlation with the lithosphere's properties.

ESTIMATION OF NOISE LEVEL IN GNSS TIME SERIES

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The presentation contains the studies upon the noise level in GNSS (Global Navigation Satellite System) time series. As the data the authors used changes of the geodetic coordinates of the ASG-EUPOS and associated (Slovak and Czech) sites. The method of precise GNSS observations processing in short-time intervals was worked out in the Centre of Applied Geomatics, Military University of Technology. The authors focus on the diurnal and sub-diurnal frequency bands (tidal) since the tidal effects influence the sites' positions the most and the model used in the standard processing software does not contain geodetic coefficients. From that reason the residual values of the geodetic coordinates time series should hold some information in the shape of coloured noise. The presentation will comprise short description of the Earth tides phenomenon, the concept of the tidal parameters determination, character of the white and coloured noise and the assessment of the noise estimation from GNSS data. Since the processed network contains above 110 sites the spatial distribution of the noise's parameters will be also investigated.

LANDSLIDES MAPPING USING AIRBORNE LASER SCANNING DATA

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Southern Poland is a region affected by strong mass-movements. According to the raw evaluations there were occurred in Polish Carpathians about 60,000 landslides. The importance of mass-movements problems has been taken into consideration on the governmental level and Landslide Counteracting System (SOP) program was launched in 2008. The main purpose of

this program is to create inventory and map all active and inactive landslides and landslide prone areas in Poland. However, in case of such gigantic work, the traditional mapping methods meet sometimes their limitations. In order to overcome some of efficiency problems the new technologies are tested. One of the most promising methods is the application of airborne laser scanning (ASL) data. Based on ASL data an extremely detailed digital terrain model could be generated, also for forested and vegetated areas where analysis of small-scale terrain relief is very difficult even during field observations. The micro relief analysis supported with 3D computer visualization helps to detect potential landslides and map and/or update maps of known landslides.

Within the presented project the ASL dataset covering 40 km² of the area near Roznow Lake in Polish Carpathians have been acquired in April 2010. The scanning resolution was 4 points/km² and LiteMapper 6800i system based on the full waveform, Riegl LMS-Q680i scanner have been used. Acquired point cloud was applied to construct DTM of 0.5 m resolution. For efficiency test purposes the detailed geological interpretation of constructed ASL DEM was focused on already well mapped large Zbyszyce landslide. The extents of the landslide, scarps and the zones of different level of activity have been mapped and then verified with field data. During the detailed analysis it was found that the level of the details of ASL DEM allows also performing morphometric analysis on landslides.

The work was financed by Polish Ministry of Science and Higher Education from funds on science in 2009-2012 as a research project number N N526 146037.

ETRS89 REALIZATION WITH ASG-EUPOS SYSTEM

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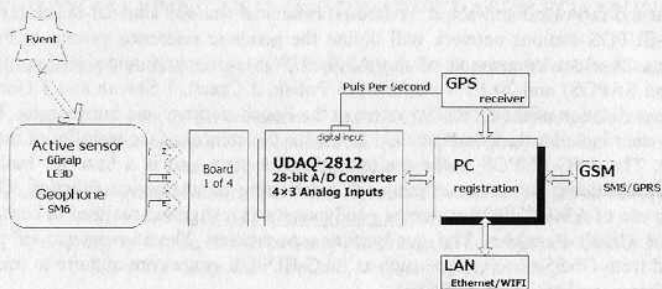
The ASG-EUPOS multifunctional system for precise satellite positioning is a part of the EUPOS project involving countries of Central and Eastern Europe. The ASG-EUPOS system will consist of reference stations such as: 68 GPS and 8 GPS/GLONASS, which were built within the realized project, 16 existing GPS, 6 GPS/GLONASS existing admitted into the system situated in Poland and about 30 foreign reference stations situated in the border zone. The ASG-EUPOS stations network will define the geodetic reference system in Poland and border zone. A close connection of the ASG-EUPOS stations, foreign stations (CZEPOS, SKPOS and SAPOS) and 20 EPN stations (16 Polish, 2 Czech, 1 Slovak and 1 German) will control the realization of the ETRS89 system at the Polish territory and border zone. The ASG-EUPOS system includes three independent levels for the control of the stability of the ETRS89 realization. The ASG-EUPOS is the multifunctional system and is a base for building own systems (applications) for users utilizing the positioning or navigation function. One of the domains to use of ASG-EUPOS system is geodynamics investigation realized in border zone of Poland and Czech Republic. The geodynamics parameters like movements of points are determined from GNSS observations such as ASG-EUPOS system and require to use correctly reference frame (realization of ETRS89).

NEW GENERATION OF MULTICHANNEL MICROSEISMIC APPARATUS AND ITS EMPLOYMENT IN EASTERN AND WESTERN BOHEMIA

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The dense seismic arrays, specific spatial distribution of seismic sensors, are used for weak earthquakes detection in eastern and western Bohemia. The first version had been deployed near Náchod in the year 2005 and the two further at Nový Kostel and Květná followed. The measurement is provided by our own data-logging system RUP2009 and three-component geophones or broadband seismometers. Such a hardware/software system can be also used for monitoring of activity at a fault zone area, so-called macro-seismic regionalization. This approach is fundamental for planning important civil engineering projects according to assumed local historical seismicity. The shapes of arrays used in all three sites are similar – three satellite sensors in the corners of a triangle and one nearby the geometrical centre. Current equipment consists of four local, almost independent, stations with 21-bit digitizers Tedia. That is why all the data is strongly dependent on the time synchronization by GPS using hardware sync-line. During the year 2010 has been developed quantitatively new A/D module with 28-bit resolution and 32-bit arithmetic in cooperation with Tedia. There are two versions – with four and twelve analog inputs. The 4-input variant replaces the original 21-bit version. The 12-input module is intended for new dense seismic array deployments. The whole set consists of four 3-channel detached boards that can be interconnected with the main one by up to 100 m long cable. This design enables to increase SNR by placing the A/D part as close to the seismograph as possible and transmit digital data to the storage. All channels are sampled coherently so all four sensors are automatically synchronized together. This feature enables to detect local events sufficiently although the sync-signal is absent. In the other words: the 12-input module is also suitable for an ad-hoc field measurement when GPS signal is hardly feasible. All operated arrays are going to be upgraded this way and some new sites, e.g. Lazy, are going to be deployed using this innovative equipment.



ASSESSMENT OF THE RECENT GEODYNAMIC ACTIVITY IN THE MIDDLE ODRA FAULT ZONE ON THE BASIS OF ANNUAL GPS MEASUREMENTS FROM THE 2008-2010 PERIOD

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In the paper results of the GPS measurements carried out in a geodynamical network in the Middle Odra Fault Zone in 2008-2010 period have been presented. That network consists of seventeen new and adapted points located along the Legnica–Wrocław–Opole axis across a distance of 160 km and in a strip of 60 km. The network included three points from the GEOSUD network. One of the points, Kłodzko (KLOD) is located in the Sudety Mts. and the two other, Strzelin (STRZ) and Strzegom (SGOM), on the Fore-Sudetic Block. In the year the geodynamical network in the Middle Odra Fault Zone has been established, the GPS Active Network (ASG-EUPOS) started operation. Among points of that network eleven are located on the research area or in its surroundings that include area of the Sudety Mts., the Fore-Sudetic Block and the Fore-Sudetic Monocline. Observations from these GPS stations have been solved as annual epoch GPS measurements together with observations from points of the research network. This has allowed for better vector construction and increased amount of the common points in GPS sessions.

The paper discusses the issues concerning assumed strategies of the solutions and results of GPS point velocity calculations on the basis of annual epoch measurements from 2008 – 2010 period. The results of gravity measurements in relation to displacements of the GPS points have been also presented.

GEODYNAMIC ACTIVITY AND MASS MOVEMENTS IN THE AREA OF STOŁOWE MOUNTAINS NATIONAL PARK

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In the 2008 – 2010 period on the area of the Stołowe Mountains National Park, GPS and gravity measurements of the research network points were realized. In the oldest part of the Stołowe Mts., the Szczeliniec Massif, observations of rock blocks displacements using geodetic methods and relative observations with TM-71 crack gauges have been carried out since the 70-ties of the 20th Century. Results of epoch GPS, gravity and geodetic observations have been the basis for assessment of the recent geodynamics of this area. The recorded mass movements in the Szczeliniec Massif indicate their relation to tectonic activity of this area.

INVESTIGATIONS OF THE ROCKY BLOCKS DISPLACEMENTS IN THE EDGE PART OF THE SZCZELINIEC MASSIF

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Paper presents results of the geodetic measurements and calculations of rocky blocks displacements in the edge part of the Szczeliniec Massif. The geodetic investigations of the mass effects are being carried out since 1972. The results of recent measurements will be compared with results from previous years. The paper shows results for the local networks located in the vicinity of the mountain lodge; in the main rocky rift "Piekielko" and in the vicinity of "old steps". The paper also presents the leveling network ties between objects, as well as the results of reference measurements between edge and bottom part of the massif. Taking account the mobility of the rocky blocks the measurements have scientific and practical application due to the safety of the intensive tourism traffic.

AERIAL PHOTOGRAMMETRY OBSERVATION OF THE SUBSIDENCE DEPRESSION NEAR KARVINÁ

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Aerial photogrammetry was chosen as an additional method of observation the subsidence depression that was created above exploited coal mining panels near Karviná. While individual points of a stabilised observation network were repeatedly surveyed by GPS, the whole subsidence depression was surveyed by the aerial photogrammetry. As this method was applied three times (during three years) we can compare its results in individual years and observe the surface changes on the undermined area. Also, a comparison was done between the points' coordinates gained from both aerial photogrammetry and GPS. The results show that the method of aerial photogrammetry enriches and complements the GPS observation in monitoring the spatial development and shape of the subsidence depression, but its accuracy may be insufficient during periods of minor exploitation.

REPROCESSING OF EUREF PERMANENT NETWORK: PRELIMINARY RESULTS AND APPLICATION FOR GEODYNAMICAL STUDIES

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EUREF Permanent Network (EPN) is a science-driven network of more than 200 continuously operating GNSS (Global Navigation Satellite System) reference stations in Europe with precisely known coordinates to realize ETRS'89 (European Terrestrial Reference System). Reprocessing means repetition of a processing of GNSS data gathered by permanent sites during long period using the newest strategy, models, software and products. The project of a coordinated reprocessing of the entire EPN, spanning the period from 1996 until 2009 is currently one of the main EPN undertakings. The purpose is to obtain homogenous time series of geodetic coordinates, which enable determination of the cumulative solution for stable reference system realization. Reprocessing solutions also give information about geodynamical phenomena e.g. velocities, strain fields and deformations. This presentation will contain the adjustments of the EPN data made by the Military University of Technology EPN Local Analysis Centre (MUT LAC) which is one of the 17 LACs currently operating in Europe. The authors made analyses using two independent softwares: Bernese and GAMIT/GLOBK and performed preliminary studies concerning PPP (Precise Point Positioning) approach to compare the results and eliminate errors propagated during differential processing and network dependencies as well.

IMPROVEMENT OF THE VELOCITY FIELD IN CENTRAL EUROPE BASED ON REPROCESSED PERMANENT AND EPOCH-WISE GPS OBSERVATIONS

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The history of GPS monitoring aimed to investigation of geokinematics in Central Europe started in 1994 with the epoch-wise Central Europe Geodynamics Project and several permanent GPS stations in the region; together data from about 30 sites were available. Since that time the number of suitable permanent and epoch stations with accessible data significantly increased to nearly 150 relevant sites. The existing analyses of the whole observations period from 1994 to 2010 suffer from inhomogeneities of various kind, e.g. due to varying GPS antennae models, reference frame evolution, improvement of troposphere modeling, etc. We will demonstrate a new complex solution for 3-dimensional site velocities which is based on GPS data reprocessed by unified procedures and models and related to homogeneous reference frame. A special attention will be paid to reliable estimate of uncertainties of estimated velocities and identification of local anomalies where the disagreement of site velocity with the regional trend is observed.

THE VALUATION OF VERTICAL CRUST ACTIVITY OF THE ŚNIEŻNIK MASSIF AND KROWIARKI AREA BASED ON MEASUREMENTS IN STATE PRECISE LEVELING

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The analyzed sequences of precise leveling include Polish part of the East Sudety Mts. - Złote Mts., Laskówka depression, Bardo Mts., Śnieżnik Massif and Kłodzko basin. In this part of the Sudety Mts. occur tectonic units: Kłodzko - Złoty Stok Massif, Śnieżnik Metamorphic Unit - SMU, Bardo Unit, Kłodzko Complex and Upper Nysa Kłodzka Graben - UNKG. In SMU are distinguished several lower rank units: Międzygórze, Sienna-Králíky, Śnieżnik, Krowiarki, Trojak, Radochów and Złoty Stok - Trzebieszowice. In UNKG there are few sedimentary basins with increased thickness of Upper Cretaceous deposits. After Upper Cretaceous the Sudety Mts. were unevenly uplifted. Cretaceous basin margin have been uplifted by about 700 – 1000m. In UNKG basin different uplift speed took place. For example Idzików brachisyncline has distinct features of tectonic horst. A number of indirect geomorphologic evidence indicates that the tectonic movements in this area are present to this time. They are now more easily identified using geodetic methods rather than geological. Results of measurements of the 1st and 2nd class national precise leveling lines were presented in the paper. Archival data from Central Office for Geodetic and Cartographic Documentation in Warsaw were used in this aim. Researches concern leveling polygon no 156, part of the Kłodzko region. Polygon 156 is created by the 1st class lines: Złoty Stok - Kłodzko and Kłodzko - Boboszków as well as 2nd class lines: Złoty Stok - Stronie Śląskie, Żelazno - Stronie Śląskie, Stronie Śląskie - Jaworek, Bystrzyca Kłodzka - Jaworek and Jaworek - Boboszków. Completeness of the archival leveling data was checked with identity of benchmarks in chosen lines. Damaged and unidentified points were eliminated. Leveling dates come from period 1883 till 2008. During the analysis benchmark assumed as stable were determined. These points were accepted as reference frame. Changes of the benchmark heights and vertical movements velocities were calculate along analyzed leveling lines. Interpretation of the research results was conducted with geomorphological conditions and geological and tectonic structures.

RESULTS OF THE GEODETIC MEASUREMENTS OF THE ŚNIEŻNIK MASSIF AND ADJACENT AREAS (SUDETY MTS., SW POLAND) FOR TAKE ON CRUST DEFORMATION DETERMINATION

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Researches for determination crust deformation in the Śnieżnik Massif and his vicinity (Sudety Mts., SW Poland) have been started in 1992. The area of investigations with attention on large morphological differentiation, forestation as well as first of all the geological and tectonic conditions, required the use of various measuring methods. The Śnieżnik network was founded in the scientific cooperation of Department of Geodesy and Photogrammetry, Agricultural University of Wrocław and Institute of Geodesy, Technical University of Brno. The network contained 27 points in the both sides of the Massif (Czech and Polish). Satellite GPS, gravimetric, classical geodetic as well as relative measurement methods were used for determination the crust deformation. Results from Polish part of the Śnieżnik network were considered in the study. At present there are 14 points, fixed as concrete observation pillars. In 2008 the investigation area was widen to assure more reliability and full opinion of the Śnieżnik metamorphic deformation. 8 points of the Waliszów network were fixed in the Krowiarki Mts. and northern part of Upper Nysa Kłodzka Graben (UNKG). Two observation campaigns were realized in this network.

Results of periodical static satellite measurements analyses were presented in the work. GPS measurements were calculated using Bernese GPS Software ver. 5.0. Received data and interpretations were compared with data from measurements in gravimetric sections. Determination of the gravity changes in the network was made by scientists from Department of Geodesy and Geodetic Astronomy at Warsaw University of Technology. The observation data have been collected from 18 years. Presented results of investigations in the presentation come from chosen periods.

GEOLOGICAL AND GEOMORPHOLOGICAL SURVEY OF THE WEST BOHEMIA SEISMOACTIVE AREA

PRELIMINARY RESULTS

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Aim of this paper is to compare how much is shape of the landscape controlled by underlying bedrock fabric. Research was focused on obtaining field data from eastern boundary of the Cheb (Eger) Basin and adjacent Svatava crystalline unit (Saxothuringian). Western boundary of the research area is defined by the NW trending Mariánské Lázně Fault Zone (MLFZ), eastern and south boundary represents deep valley of the Liboc creek and Horka dam. The northern boundary is represented by the road from Luby to Libocký Důl. The total area researched is about 30 square kilometers. Field work consisted of several mapping campaigns during the year 2010.

Geological part of work was focused on search for outcrops of rocks for structural and geological analysis, geomorphological part focused on documenting of shape of the relief and landscape elements together with search for springs and swamps.

The Cheb Basin was developed during Upper Tertiary and it covers granites and metamorphosed Lower Palaeozoic series of Saxothuringian. Assymetric basin dip to the east where is faulted by the MLFZ. Upland east of MLFZ is formed by foliated metamorphic rocks of the Svatava crystalline. Metamorphic rock composition changes from lightly metamorphosed phyllites on the north through mica schists in the middle and garnet bearing gneiss and granite on the south. Foliation in metamorphosed rocks mostly strikes E-W, with dip towards N. Foliation dip is changing from low on the north to moderate in the area of Nový Kostel on the south. Further to the south in the area around Kopanina, foliation is often detaily folded with steep dip up to 80 towards S. Faults forms two distinct groups: The first one is striking N-S with steep dip, The second with strike NW-SE dipping steeply toward NE. Main joint set has variable strike between NNW-SSE to NNE-SSW.

Main geomorphological features consists of low relief Cheb Basin with average elevation 450 m a.m.s.l., basin gradually transits to upland peneplain with elevation 600-620 m. Upland is cut by fluvial erosion that formed valleys up to 150 m deep. Shape of valleys profiles depends on bedrock geology. In the northern part around Luby there are wide v-shaped valleys, whereas in the southern part around Kopanina there are narrow v-shaped valleys. Width of valleys depends on rock composition, phyllites are easily eroded therefore valleys are wide, on the other side gneiss is more resistant to erosion and valleys are narrow. The main streams have two dominant run-off directions: towards SE and towards SW.

LARGE SIGNALS OF TILTING OF FOUNDATION OBSERVED IN GEODYNAMIC LABORATORY OF SRC IN KSIAZ PRESUMABLE CONNECTION WITH EFFECT OF PLATE TECTONIC MOTIONS

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In 2003 system of two water-tubes tiltmeters (WT) was installed in galleries of the Geodynamic Laboratory in Ksiaz. Tiltmeters consist of two several dozen meters length tubes, perpendicular each other and partially filled with water. Principle of work of instruments bases on the law of hydrostatic equilibrium. The interferometer system for continuous measurements and registrations of ultra small variations of water level was applied. This system enables permanent measurements of water level variations with nanometer accuracy corresponding to 0.005 [mas] of plumb line variation. WT tiltmeters possess advantages such as: high and stable resolution of measurements, stable sensitivity of measurements, stable and well determined azimuth of measurements, possibility of elimination of instrumental drift. Valuable property of new tiltmeters, allowed us to investigate long period or systematic phenomena. Since 2003 we observed several events of long-standing, extremely strong clinometric signals. The largest signals happened without seasonal correlations in different months. Magnitudes of strong signals exceeded hundred of [mas] and time of durations amount dozen or so days. Characteristics of these signals such as: repeatability, time of durations, irregularities of appearance and magnitude of phenomenon indicate relations with tilting of foundation. Other potential reasons of strong non-tidal clinometric signals of loading or Newtonian origin and associated with large mass displacements are to small to explain magnitude and time of duration of observed signals. Detailed analysis of strong non-tidal signals discloses us that whole strong non-tidal signals observed in Ksiaz consist of two parts: symmetric and asymmetric one. Symmetric part of signals describes effect of tilting of whole massive of Ksiaz (tilting of foundation) while asymmetric part describes effect of lifting and lowering opposite ends of the tubes of tiltmeters. Magnitude of asymmetric signals indicates that value of displacement amount of several hundreds of millimeter. Asymmetric effect is especially visible on tube named 0304. Relative displacements of fragments of massive (lowering and lifting) probable take place on faults crossing water-tubes 0304. It is very characteristic that asymmetric signals accrue during strong non-tidal effects only. For other large scale signals such as tidal, non-tidal, loading and Newtonian as well as tilt effects of Earth free oscillations observe signals are exactly symmetric. Asymmetric part of strong signals indicate that strong tilt effects are of local origin in space occupied by the tubes of tiltmeters <100 [meters]. Correlation between resultant tilts of strong signals and mean direction of plate tectonic motions in Central Europe indicate on tectonic origin of strong clinometric signals.

EVALUATION OF THE SUBSIDENCE BASED ON INSAR AND GPS MEASUREMENTS NEAR KARVINÁ

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Differential interferometry (DInSAR), a remote sensing technique, allows detect ground surface deformation by the processing of SAR satellite images. In the study area were SAR images processed from the ALOS satellite (sensor PALSAR) with 46-day repeat cycle. Between February 2007 and May 2008 was created 5 differential interferogrammes (with time-continuing span) from which was a subsidence calculated. Application of PALSAR's wavelength of 23,6 cm (L-band) allows measurement of subsidence in the undermined area up to decimeters per year, even in the vegetated areas. To verify the procedure of differential interferometry for the purpose of monitoring the subsidence, an area through active underground mining in the region of Karvina was selected for this purpose. Since the end of 2006, available data have been obtained by regular observation of GPS monitoring station established in the study area. The spatial position of the array of points of named observation station is been surveyed approximately ten times per year using static GPS method. On the basis of independent evaluation of data obtained by both methods with subsequent comparison, we have obtained a good source material for creating a complex view on spatial-temporal changes in the study area.

DETERMINATION OF THE EARTH'S SURFACE BY LOCAL MASS LOADING AND TEMPERATURE EFFECTS

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The mass of big building cause a deformation of the Earth crust up to long distance from area of realization. The elastic and rheological effects are modeled as viscoelastic and plastic. In both cases exists new factor - time. More deeply knowledge of mechanical properties of materials and modern computer equipment allow construct very precise model reaction of the Earth surface on loading in time. Geodesists and geophysicists need to know this laws of deformation and theirs time evolution for geodetic nets design, for analysis of repeated measurements or analysis time series. The presentation contents the mathematical modeling of the Earth elastic surface deformation caused by symmetric loading of its boundary, time evolution of vertical displacements and local deformation caused by temperature effects.

VERIFICATION OF THE MODELS OF RECENT VERTICAL MOVEMENTS OF THE EARTH CRUST SURFACE ON THE AREA OF POLAND ON THE BASIS OF EPN STATIONS DATA

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Known models of recent vertical movements of the Earth crust surface of the area of Poland were processed on base of data of geometric state leveling network first and second classes, in the form of contour line map. Map by Wyrzykowski (1971) was based on results of measurements from years: 1871-1882, 1926-1937 and 1952-1956. Second map of the same author from 1985 year takes into consideration also measurements from years 1975-1977. The newest results of assignment of recent vertical movements of the Earth surface for Polish territory were published by Kowalczyk in 2006 year. On base of repeated measurements of state precise leveling, executed in years 1974-1982 and 1997-2003, the map of speed of modern vertical movements has been processed using least squares collocation method. Achieved results characterize vertical movements of the Earth surface with reference to tide gage in Wladyslawow, located on polish coast of Baltic See. Presently, after about 15 years of satellite observations on permanent stations belong to the GPS European Permanent Network (EPN), verification of mentioned models is possible on the base of independent measurements. As resolution of stations for area of polish country is not sufficient, model processed from satellite data was determined for whole area of Europe and it was confronted with earlier (leveling) models. Model processed on base of GPS data is a free-for-all product of EPN network elaboration too. Comparison of leveling and satellite models indicates defect of reference distinctly resulting from see level variability.

POSSIBLE APPLICATIONS OF DETAILED EARTH'S GRAVITY FIELD

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Earth gravitational model EGM08 derived from GRACE satellite data and a worldwide set of terrestrial gravity anomalies is complete to *degree and order 2159 (for selected degrees up to 2190)* in the spherical harmonic expansion. Thus, it yields globally an unprecedented *precision and resolution* for geoidal undulations and other functionals of the Earth gravitational potential. One of many geophysical applications of the model is possible. We present two applications: detections of impact craters and geomorphological applications. Both are based on computed gravity anomalies and second radial derivatives of the disturbing gravitational potential in different areas. At first in areas of known impact craters we verified the existence of all geologically confirmed craters with a diameter larger than approximately 30 km. Moreover, we have found few new candidates for the impact craters closely connected with and in vicinity of

the existing structures like Chicxulub (Mexico) and Popigai (Siberia). At second, application in areas of large/small tectonic motion to find correlation between active/non-active structures of Earth's surface and behaviour of the second derivatives of the geopotential.

IDENTIFICATION OF PERIODIC CHANGES IN THE POINT POSITION USING VARIOUS GPS TECHNIQUES

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Earthquake events cause effects such as ground shaking or permanent surface displacements, depending on distance from epicenter. At the sites located farther away from epicenter only the vibrations of the ground without permanent surface displacement may be observed. These periodic oscillations can be detected with aid of positioning techniques, and its amplitude and period may be determined. In the article the examples of earthquake impact on sites distant from epicenter are shown. Possibilities of various GPS techniques: static, kinematic, RTK and RT PPP have been analyzed. Presented results came from observations of the real (Sumatra 2004, L'Aquila 2009) or simulated events - measurements conducted with rotating GPS antenna mounted eccentrically.

GRAVITY SURVEY OF SUDETEN MARGINAL FAULT BETWEEN ZŁOTY STOK - SREBRNA GÓRA

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The Sudetic Marginal Fault is the longest, morphotectonic threshold in Poland, about 150 km of total length, stretching from Jeseník (Czech Republic) to Sichowa near Złotoryja (Poland). Its extensions of both towards NW and SE do not create morphotectonic scarps any more. This fault has Variscan foundations and was reactivated in the upper Oligocene. It was also active during whole Neogene, particularly in Pliocene. In the Pleistocene, tectonic activity increased at the end of ice ages probably induced by isostatic movements. From the Lower Miocene to the present day, along the Sudetic Marginal Fault tectonic grabens have been formed. They are filled with ca 50 to 660 meters of sediments. The Sudetic Marginal Fault separates the Sudety Mts from the Fore-Sudetic Block. Currently the Fore-Sudetic Block is dropped against the Sudety Mts from ca 200 m in the NW part to 1000 m in its SE part. On the contrary, in the late Paleozoic Fore-Sudetic Block formed opposite position of hanging wall against the Sudety Mts. Previously it was assumed that the morphological threshold of the Sudetic Marginal Fault is erosionally retreated of about 200-400 m from the present surface of the fault. Conducted gravity survey constitutes the continuation of works begun in the area of the Bila Voda (Czech Republic). The destination of this observation is getting to know the detailed location of the

Sudeten Marginal Fault. The size of the drop and slope of fault zone. Such gravity research so far were not still conducted. The base of the gravimetric method is the gravity effect described with the law of universal gravitation. This method is examining changes of the gravitational field, and exactly change of his vertical component called the force of gravity (generally named gravity). Changes of the value of this force are connected with a presence of the diversity in the distribution of masses of the rock centre. Gravity anomalies are returning surface copying this distribution. Its size is a function of the difference of the density between individual kinds of rocks building geological forms and surrounding them, depths of the location and sizes of these forms. This distribution is the base to quality-quantitative interpretation, as a result of which the connection of the measured gravity distribution with the geological structure is determined. A Polish fragment of the Sudeten Marginal Fault was provided with gravity survey. On the basis of geological data three areas were marked out at the section from the Złoty Stok up to the Srebrna Góra. Research was performed in three profiles. Its length was chosen in order to provide total covering with measurements area in which the gravity effect generated by the offset is included. Distribution get as a result of gravity observation along profiles are characterized by a considerable horizontal gradient. Such a type of the gravity distribution is characteristic of areas, where in geological structure is watching a contact of rocks with considerable contrast of the volume density. In received gravity distribution it is visible, that curves differ from each other in the amplitude as well as slope of fault zone. It is attesting to the fact that the Sudeten Marginal Fault is divided into area about the different drop and different slope of fault zone. Gravity modelling will let the size of this discharge and the inclination for every of research area.

STRESS-STRAIN CHARACTERISTICS OF THE KRUŠNÉ HORY GRANITE AND ITS RELATIONSHIP TO SEISMIC VELOCITIES

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We have studied the geophysical, physical, and geochemical parameters of the Podlesí granites in the western part of the Krušné hory Mts., near the village of Potůčky. The granites represent a fractionated intrusion within the Nejdecký Massif. In total, the studied well is about 300 m deep with samples collected at depths of between 25 and 110 metres. The method used to specify the deformational characteristics of the rock is based on the experimental loading of the sample with uniaxial strain. The shear and longitudinal deformation of each sample was measured using a resistive strain gauge (20/120LY41 Hottinger Baldwin Messtechnik) placed directly on a given sample. Intermittent loading of the samples proceeded using a uniform gradient of axial strain of 1 MPa.s⁻¹. The samples were subjected to five separate loads. During the tests, the following parameters were recorded: stress, longitudinal deformation, and shear deformation. These data were used to calculate Young's modulus (Fig. 1, right axis - Ed tenzo), static Young's modulus, and Poisson's ratio. The seismic velocities of P-waves and S-waves were measured using ultrasound scanning. Both dry natural and water saturated samples were analysed. The ultrasound scanning system consisted of 4 piezoelectric sensors, 4 ultrasonic pulsar receivers, and a digital oscilloscope recorder. The wave frequency was 1 MHz. The velocities of the P-waves vary from 4580 m.s⁻¹ to 6145 m.s⁻¹. The velocities of the S-waves

vary from $2950 \text{ m}\cdot\text{s}^{-1}$ to $3750 \text{ m}\cdot\text{s}^{-1}$. These velocities generally increase with the depth down the well. These data were also used for the calculation of Young's modulus (Fig. 1, left axis - Ed sat, Ed dry) and Poisson's ratio number. This work has been funded by the Ministry of Industry and Trade of the Czech Republic (FR-T/1/367) and by the Institute of Rock Structure and Mechanics AS CR, v.v.i. (A VOZ30460519).

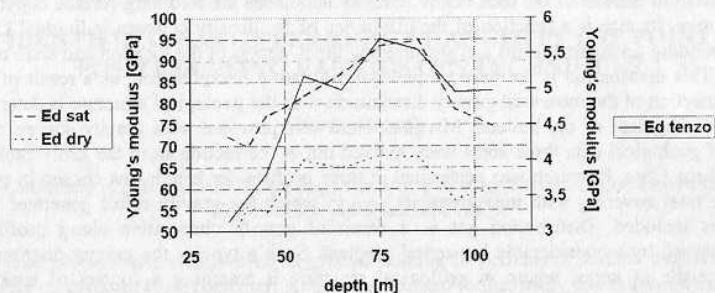


Fig. 1 Calculated Young's modulus (Ed) for both methods: Ed sat - water saturated samples measured using ultrasound scanning, Ed dry - dry natural samples measured using ultrasound scanning, Ed tenzo - dry natural samples measured using a resistive strain gauge (left axis - Ed sat, Ed dry, right axis - Ed tenzo).

GEODYNAMICAL STUDIES USING GRAVIMETRIC METHODS IN THE ŚNIEŻNIK MASSIF

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Authors of the paper have reported over ten year period of gravimetric investigations, since 1992, in the frame of geodynamical studies in some parts of Sudety Mts. Gravity change measurements using static gravimeters LaCoste&Romberg carried out in Eastern Sudeten have been performed within the frame of one from the segments of monitoring and control system implemented on geodynamic polygon Śnieżnik Massif. The most interesting situation in Śnieżnik Massif has been appeared, there was pointed out a clear tendency of gravity arising on points in lower parts of geodynamic test field and decreasing of gravity in upper parts. In the paper there are reported also our works connected with determination of absolute gravity using FG – 5 instrument on some points in adjacent areas in relation to the Eastern Sudety. They present the reference gravity level for interpretation of gravity changes pointed out in Śnieżnik Massif. The authors suggest for near future also the necessity of an installation of the gravimetric calibration base-line in a vicinity of the area under investigation with possible great value of gravity differences, stabile monumentation and marks conservation. It is obvious that this net ought to be connected with Czech national gravimetric network or a local gravity base-line on Czech part of Eastern Sudety Mts. to

assure the homogeneity of searches. The full and correct geodynamical interpretation of recognized changes will be possible after taking results of other kinds of geodetic investigations taken at the same period.

APPLICATION OF PERSISTENT SCATTERERS INTERFEROMETRY FOR LANDSLIDE MONITORING IN THE VICINITY OF ROZNOW LAKE IN POLAND

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The authors present the preliminary results of the analysis of two archival SAR datasets acquired by ERS-1/2 satellites of the same area of Roznow Lake in Southern Poland. Both datasets cover the same period of 8 years (1992 – 2000) and refer to the same area by the 50% of overlap between the neighboring satellite tracks. The main purpose of this analysis was to derive the overlapping data about deformation velocity calculated using PSI (Persistent Scatterers Interferometry). The presented PSI results refer to PS (Persistent Scatterers) located on active landslides and therefore represent landslide movement. In Polish Carpathians, due to sparse urbanization, vegetation and rough relief the obtained PS density is usually not very high and generally difficult to interpret. The application of two overlapping datasets, where both observe the same phenomena, allow to cross-validate the data by identification of common PS points. For two datasets acquired from different tracks, usually many PS are not common and occur in the different locations. Such situation could be explained by the difference between the incidence angles for both acquisitions. In case of two tracks and therefore different terrain objects might act as PS. By joining the PS point sets from such neighboring tracks the density of PS could be significantly increased.

In order to perform a PSI analysis of Roznow Lake the data acquired from 179 and 408 tracks have been used and a few hundred of PS were obtained from PSI processing. For both tracks similar deformations velocity were obtained within a range of $\pm 6 \text{ mm/yr}$. The PS points on active landslides are usually related to the buildings (walls, roofs) and roads affected usually by high risk.

Subtle deformations measured with PSI could be classified as slow movements. They do not represent a typical landslide movement which is usually higher and cannot be measured with InSAR. The slow movements should be treated as preliminary deformations that may occur on landslide-prone areas before landslide occurrence. Within such approach the PSI technique becomes an important tool to detect and map landslide-prone areas within urbanized areas.

The work was financed by Polish Ministry of Science and Higher Education from funds on science in 2009-2012 as a research project number N N526 146037. SAR data from ERS-1/2 satellites are courtesy of ESA within a framework of C1P.3915 project.

UNCONSTRAINED SOLUTION OF GNSS TOMOGRAPHY

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The central problem in GNSS tomography retrieval of water vapor content is the insufficient number of scanning rays. The scanning rays are simply observations of Slant Wet Delay between satellite and the receiver, so the number of SWD's is linked with the number of visible satellites, number of receivers, time interval of measurements and estimation, cut of angle, horizon obstructions. To obtain the 3D picture of water vapor one usually need to add constraints in the form of pseudoobservations, values direct constrain, or sigma limiting. This kind of constraints improves the solution raising the rank number of the design matrix but on the other hand produce somewhat artificial results. To overcome such factors in the solution, author proposes the free Singular Value Decomposition solution and incremental update of the values. The presented result shows that this method might be incorporated into presently working GNSS tomography model.

COHERENCE BETWEEN GEOPHYSICAL EXCITATIONS AND CELESTIAL POLE OFFSETS

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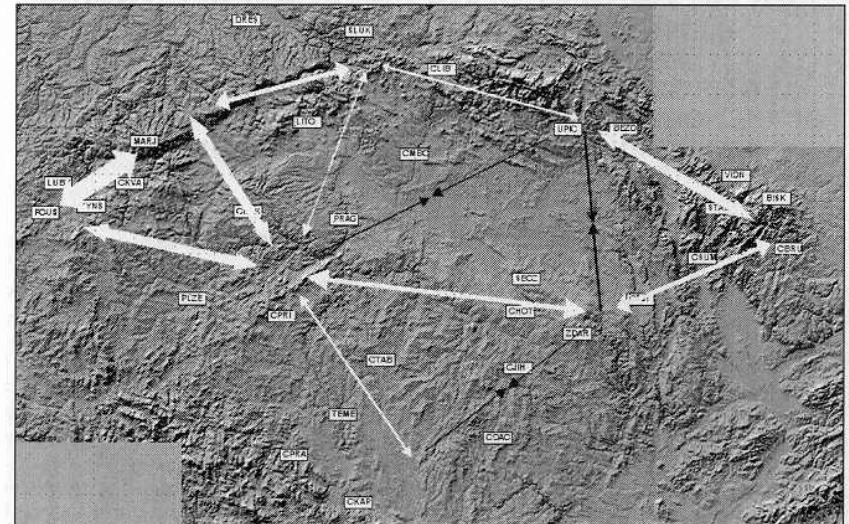
Celestial pole offsets are the displacements between the observed position of the Earth's spin axis in space and its position predicted by the adopted models of precession and nutation. At present, the models are IAU2006 and IAU 2000, respectively. The celestial pole offsets are regularly measured by Very Long-Baseline Interferometry (VLBI), the observations being coordinated and published by the VLBI Service for Geodesy and Astrometry (IVS). These offsets contain a mixture of several effects: the unpredictable free term, Free Core Nutation (FCN) that is due to the presence of the outer fluid core of the Earth, forced motions excited by the motions in the atmosphere and oceans, and also imperfections of the adopted precession-nutation models. The geophysical excitations are also available, as determined by several atmospheric and oceanographic services. The aim of this paper is to compare the time series of these excitations with the observed celestial pole offsets and estimate the level of coherence between them.

THE HORIZONTAL STRAIN FIELD FOR THE BOHEMIAN MASSIF

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GPS satellite signals monitored on permanent stations of the Geodynamic Network of the Academy Science (GEONAS) and of the Czech Office for Surveying, Mapping and Cadastre (CZEPOS) were used for horizontal strain rate evaluations of selected parts of the Bohemian Massif. The stations are situated in and/or near the geologic structures, where neo-tectonic activities are expected. GNSS data were processed by the Bernese software v. 5.0. The regional pattern of the horizontal strain field for the Bohemian Massif (see the Figure) was assessed from the horizontal (North and East) velocity movements determined from whole station observation periods. Since at present the Bohemian Massif is still under northwards Alpine orogenic processes, its recent strain field has to be affected by these forces. The strain extensions in the east-west directions of the Massif are evident and in its western part they take on considerable values. Some slight stress compressions have been detected in the central areas of the Massif. The pattern of the strain field will be discussed and other additional observations and interpretations will be delivered.



HORIZONTAL STRAIN, $^3\text{He}/^4\text{He}$ RATIO AND INTRA-PLATE EARTHQUAKE SWARM

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The West Bohemia / Vogtland region, central Europe, was affected by volcanic activity in the Late Tertiary and Quaternary. The present magmatic intra-plate activity is representing by the rise of fluids into the upper parts of the Earth's crust from the lower crust or from the lithospheric mantle. It is joined with increase of geodynamic mobility of the territory and by possibly generation of earthquake swarms. Two permanent GNSS stations are located in the region in which the $^3\text{He}/^4\text{He}$ ratio variations were observed. Their position data were used to calculate the time variations of the horizontal strain field between these two stations and were compared with the $^3\text{He}/^4\text{He}$ ratios and earthquake swarm occurrences. The strains and $^3\text{He}/^4\text{He}$ ratios displayed a positive correlation which supported the earlier opinions on the dependence of the intensity of gaseous flows on the dynamics of the region. The time variations of these two quantities indicated the presence of compression and extension phases in the evolution of the region. When the compression phases calmed in their regional activities the earthquake shocks occurred. The observed positive connections could be applied in future at selected regions in earthquake forecast procedures.

RELIEF OF THE CRYSTALLINE COMPLEX AND ITS GEOPHYSICAL INTERPRETATION IN SUBSURFACE OF THE NORTHERN PART OF THE MNICHOVHRADIŠTĚ BASIN AND WESTERN PART OF THE KRKONOŠE PIEDMONT BASIN (NORTH BOHEMIA).

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Correlation of boreholes and geophysical data provides the framework for 3D modelling of subsurface of the northern part of the Mníchovohradiště and western part of the Krkonoše Piedmont basins. The information from boreholes database and interpretation of the seismic profile 31 enabled construction of 500 m x 500 m grid resolution model the crystalline basement and relief of the Permo-Carboniferous volcano-sedimentary complex. Simultaneously the extension of rhyolite ignimbrite bodies was established. The minimum gravity anomaly in the Mimoň – Český Dub – Turnov – Mníchovo Hradiště area indicated presence of „light“ granitic rocks and most probably also the deeper source (up to 10 km) for volcanism. Moreover, the highest volume of ignimbrite bodies with thicknesses up to 180 m is concentrated above this minimum gravity anomaly area, which can be to the relation of the source of an alkaline volcanism producing rhyolite ignimbrite deposits.

MEASUREMENT OF INDUCED STRESS CHANGE DURING LONGWALL EXPLOITATION

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This paper describes the first experience from in-situ determination of the total stress tensor changes during a long wall extraction. A device using measurement of local deformations on conical ended borehole bottom was used for long term monitoring of stress changes induced by underground mining activity. The problems of rock stress and its measurement have been investigated in the Institute of Geonics for a long time. At present, we need a method for determination of stress and its changes as reaction to the impact of the underground human activity. The paper deals with principles and used method of stress measurement, basic description of the equipment and experiment in situ. A new device for determination of stress change tensor was developed on the basis of strain measurement applied to a conical shaped borehole bottom. Within the frame of this development a special probe interlocked to data logger was realized. This type of device was used for the long-term monitoring of the stress – strain changes.

MOVEMENT DYNAMICS AND CHARACTER WITHIN THE ZONE OF THE SUDETIC MARGINAL FAULT RECORDED IN THE PERIOD 2002 – 2010

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Results of a long-term monitoring undertaken during the period 2002-2009 in Sudeten Marginal Fault Zone are presented. An earlier study evidenced a widespread nature of recent movements in Europe. A pulse followed by a period of increased geodynamic activity was recognized in broadly simultaneous displacements recorded in different European countries during period 2003 - 2005. After several more calm years, the geodynamic activity in Europe 2007 renewed. The question may be if this is to be a new phase of increased geodynamics or continuation of the earlier that has appeared since 2003. In any case, it was in the middle of 2007 when remarkable vertical displacements reaching 0.5 to 1 mm were registered on tectonic structures across central Europe. Reactivation occurred on Sudeten Marginal Fault in the middle of 2008, when relaxation connected with remarkable vertical displacements occurred along the fault. Similar situation can be found for example in central Apennines. In Norcia vertical acceleration occurred in the middle of 2007 and continued during 2008 when a remarkable oblique movement was recorded in Colfiorito. Thus, a certain analogy is found between movement development in central Italy and central Europe. Accelerated movements occurred across Europe, and started from mid 2007. However, there is one characteristic change. The new activity developed opposite movements.

STUDY OF SUBSIDENCE USING FEM AND STATISTICAL ANALYSIS ON SELECTED LGOM AREA

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This paper presents the method of statistical verification of different physical finite element models by using precise leveling measurement's results. The most critical problem in deformations analysis of mining areas in tectonic zone is to obtain real characteristics of material, because of very different rock-mass properties and to create correct contact on fault's zone. Physical models were built by using laboratory research of parameters characterizing rock – mass properties. Fault's contact zone was created by different methods and after that was controlled by using statistical method to find the most correct solution. The study proves that the different finite element models can be verified by using leveling measurement's results and statistical analysis.

GEOLOGICAL CONDITIONS AND LOCAL CHANGES OF PLUMB LINE DIRECTION

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The paper presents local changes of plumb line direction on area of Inowrocław. The changes were determined by geodetic (GPS, leveling) and gravimetric survey results. The presented conclusions point out that increasing resolution of a precise geoid model on areas with variable distribution of rock mass is necessary. The final results of the paper are suggestions concerning a practical method applied to obtain proper values of plumb line deflections. The presented approach to determination of local deflection of plumb line and its errors may be useful for further detail research for making of more precise models of geoid.

THE RECENT PROGRESS IN THE NON-RIGOROUS METHOD

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Orientation of the Earth's body in space is described by Earth orientation parameters, EOP, which tie Earth-fixed coordinate system ITRS to celestial reference system ICRS. The relation is mathematically described by the transformation equation holding the resolutions B1.6

„Precession-Nutation Model“, B1.7 „Definition of Celestial Intermediate Pole“ and B1.8 „Definition and Use of Celestial and Terrestrial Ephemeris Origin“. The equation, which is function of station position vector and EOP, plays the key role in our non-rigorous method. The basis idea given by Kostelecký and Pešek is to combine station position vectors in the celestial system using least squared adjustment. The method has been improved several times in last decade. Firstly, we found out the way how to control smoothness of EOP results, secondly, we implemented modified Cholesky decomposition method in order to solve huge sparse matrix of normal equations. Recently, we tried to solve station position residuals for each epoch instead of computing parameters of seven-parametric transformation for each technique (GPS, SLR, VLBI). The results are compared with the terrestrial reference frame ITRF2005 and IERS C04 series.

ACTIVE FAULTING ON SUDETIC MARGINAL FAULT; BÍLÁ VODA SITE

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The NW-SE striking Sudetic Marginal Fault (SMF) controls the pronounced morphotectonic escarpment of the Sudetic Mountains for a length of 130 km. The mountain front was investigated at the locality Bílá Voda (Czech Republic). We performed five trenches perpendicular and one along the SMF, which revealed subvertical strike-slip fault zone (striking 135°-150°) dividing Paleozoic crystalline rocks (phyllonites, schists, granitic aplite) and Late Pleistocene colluvial deposits overlaying warped Miocene sediments. The main fault of the zone has a flower structure character, typical for prevailing horizontal movements. The results from the trenches show several repeated movements during late Quaternary. Due to lack of kinematic indicators in trenches perpendicular to prevailing movements, the sense of the strike-slip is still under investigation.

Time constraints of the movements documented in the trenches are based on the relative age of the late Pleistocene fault-related colluvial deposits, radiocarbon and OSL dating. The fault-related colluvial deposits include local material, tectonic breccia and pebbles of erratic nordic material coming from glacial deposits, while the last continental glacier reached the study area in Elsterian 2 (400-460 ka). OSL dating of fluvial units within these post-deglaciation deposits showed their age as 20-25 ka. These deposits are cut by younger individual faults of the fault zone, which are concealed by the geliflucted layers. The latest possible time when the gelifluction could have occurred was during Late Glacial conditions, prior to the onset of early Holocene warming (15-11ka). The results show at least 3 larger faulting events/earthquakes occurred in late Pleistocene between 11 ka and 25 ka BP. The youngest prehistoric earthquake (probably horizontal movement with some vertical component) displaced even the geliflucted layers, while the vertical displacement made up around 35 cm. These displaced layers are concealed by the recent Holocene colluvium (800±50 yrs BP). The amount of this youngest movement is in accordance with the authors published results from trenching at the site Vlčice u Javorníka, and based on the empirical relationship 'magnitude versus maximum vertical displacement', the minimum moment magnitude was estimated to be M 6.3.

PRELIMINARY RESULTS OF REPEATED MEASUREMENTS IN LOCAL GEODYNAMIC NETWORK MORAVA

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Local geodynamic network MORAVA was established for the purpose of monitoring the supracrustal blocks motions at the Czech Massif and Alpine-Carpathian Arc border, which is formed by Neogene and thick Quaternary sediments. Initial project realized in years 1994-1996 passed as project of Grant Agency of Czech Republic Nr. 105/94/J124. Applicants of the project were TU Ostrava, Faculty of Mining and Geology, and CTU Prague, Faculty of Civil Engineering. In 2010, after 16 years pause, the project had been partially continued by BUT Brno internal research project which included reobservation of 4 points at South Moravia. The measurements followed the monitoring of movement trends along the Čebín-Diendorf Tectonic Zone. Basic results of the repeated GPS measurements are presented in the paper, which revealed surprising information about movements of some blocks at the Czech Massif and Western Carpathians border. Problems of the MORAVA network point monumentations, identification and renewal, measurement methodology, and data processing procedure are also discussed.

EVOLUTION OF THE NACHOD BASIN: A PULL-APART SEGMENT OF THE SOUTH-SUDETIC BASIN SYSTEM

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The Mnichovo-Hradiště Basin, the Karkonosze Piedmont Basin, the Trutnov Basin, the Nachod Basin and the Nysa Kłodzka Trough, they all compose a regional system of tectonically controlled depressions – the **South-Sudetic Basin System (SSBS)** – that is evidently related to a WNW-ESE trending, regional-scale fault system. The horizontal component of in the western segment of the SSBS reflects a dominantly sinistral sense of the of tectonic transport along the same faults and fault sets what is documented by structural features only in the Cretaceous cover. It can be explained by progressive opening (from the west to the east of the SSBS) of individual basins between the late Carboniferous and the late Cretaceous to Neogene (Fig. 1). The palaeogeographic patterns were strictly related to the borders of the Nachod Basin only in the Saxonian and Neogene (up to the Recent), as documented by depocentres, palaeotransport directions and facies distribution in the sedimentary rocks. During the late Permian the Nachod Basin was open towards the west and closed from the east. The palaeocurrent indicators are parallel to the axes of tectonically produced depressions (grabens, palaeovalleys?) and all of them are consistently directed westwards. The rhomboidal shape of the Permian outcrops zones and the location of the sediment thickness maxima within the Nachod Basin suggest a pull-apart origin of the basin. During the Permian, the eastern

termination of the Nachod Basin was constituted by a fault that continued into the strike-slip Poříčí-Hronov Fault Zone that terminated the basin from the north. The southern termination of the basin was constituted in the Permian by Česká Skalice-Spalona Fault Zone (Fig. 2).

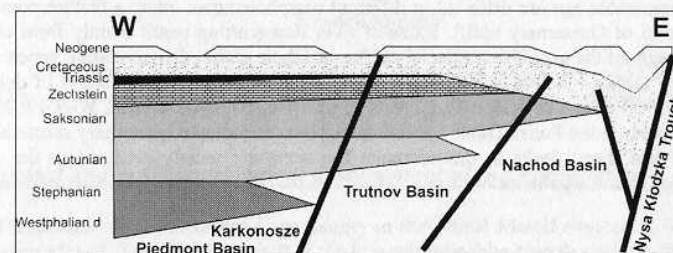


Fig. 1

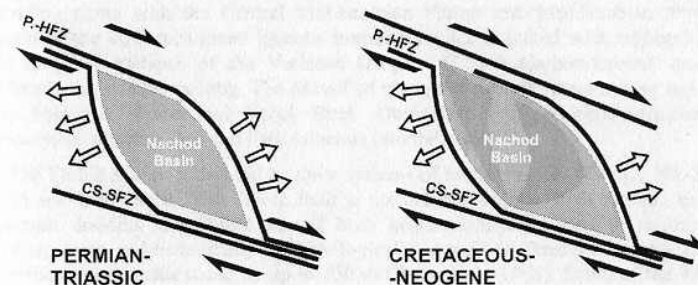


Fig. 2

PLEISTOCENE TECTONIC ACTIVITY OF THE POLISH WESTERN OUTER CARPATHIANS: INSIGHTS FROM FLUVIAL TERRACES

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In the western part of the Western Outer Carpathians, middle and late Pleistocene reactivation of early Neogene thrust surfaces was suggested. Differentiated mobility of reactivated as normal Miocene faults (oriented (N-S to NNW-SSE and NNE-SSW) in the medial portion of the Dunajec River drainage basin appears to be indicated by the results of long-profile analyses of deformed straths, usually of early and middle Pleistocene age. In the Pliocene and Quaternary the Polish Carpathians witnessed differential vertical and some remnant horizontal movements, resulting in the formation of elevated and subsided areas. Morphological examples of Quaternary tectonic activity include, i. a., disturbed longitudinal profiles of strath terraces. Valleys of the Outer Carpathians bear 5 to 9 terrace steps of Quaternary age. Most of Pleistocene terraces are strath or complex-response terraces; the Weichselian and Holocene

steps are usually cut-and-fill landforms, except those located in the neotectonically elevated structures, characterised by the presence of young straths. Longitudinal profiles of individual strath terraces frequently show divergence, convergence, upwarping, downwarping, or tilting that can be indicative of young tectonic control. Moreover, the size and rate of dissection of straths of comparable age are different in different morphotectonic units; a feature pointing to variable pattern of Quaternary uplift. Rates of river downcutting result mainly from climatic changes throughout the glacial-interglacial cycles, but their spatial differentiation appears to be influenced by tectonic factors as well. Examples based on detailed examination of deformed straths and fluvial covers in selected segments of the Soła, Skawa, Dunajec, Wisłoka, Jasiołka and Wisłok rivers in the Polish Outer Carpathians appear to indicate Quaternary reactivation of both normal and thrust faults in the bedrock. The latter are mostly confined to the eastern portion of the Outer Carpathians.

Excursion guide

THE TŘEBÍČ FAULT AND ITS MULTIPLE MORPHONEOTECTONIC MANIFESTATIONS

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Geological and geomorphological development of the Třebíč area

The Třebíč fault is an important discontinuity in the Třebíč Massif situated in SE part of the Bohemian Massif. The Třebíč Massif is the largest durbachite complex within the framework of the Bohemian Massif. It belongs to younger post-tectonic bodies (approx. 335-305 Ma) intruding along with the Central Moldanubian Pluton into Moldanubian crystalline rocks. Origin of the both mentioned igneous intrusive bodies is linked with regional extension and post-orogenic collapse of the Variscan Orogene (Lower Carboniferous), accompanied by infiltration of mantle melting. The Massif of triangular form is found among towns Jaroměřice nad Rokytnou, Polná and Velká Bíteš. Durbachite has porphyric structure with large phenocrysts of orthoclase and dark minerals (amphibole).

The Třebíč Massif is divided by three systems of faults, namely NW-SE, NE-SW (e.g. Bíteš fault) and E-W faults. The Třebíč fault is normal, transversal, fault running in the east-west direction dividing the Třebíč Massif both geometrically, on smaller southern and larger northern parts, and tectonically and lithologically as well. Differences in denudation levels due to vertical movements could be up to 750 m (Bubeníček, 1968). South of the Třebíč fault run two parallel faults - the Klučov fault and the Výčapy fault which were used for later intrusion of younger aplitic tourmaline granite. Both faults filled in intrusions form two structural ridges and both ridges wider elevated form known as the Klučov Horst (Koutek, 1964).

Surface of the Třebíč Massif tend to form depressions surrounded by a range of hills, formed by the metamorphic aureole, namely on west and north sides, and with a range of rounded tors and boulders. Described topography agrees with the long-term platform regime of weathering lasting over a greater part of Mesozoic and Cenozoic. The Třebíč fault has played an important role in the river network setting, nevertheless passive. The Jihlava River uses conducting effect of the Třebíč fault and runs from west to east and in 8,2 km long reach between Třebíč and Vladislav forms deepened fault-guided valley. Besides this, the fault separates different types of durbachites north and south of Jihlava River Valley.

Investigations of morphoneotectonic activity of the Třebíč fault have been based on identification of changes in drainage patterns of southern parts of the Třebíč Massif and vertical movements assessment derived from mineralogical composition of paleo-fluvial gravels, products of rock weathering and ferric solution migration. Landscape topography in southern surrounding of Třebíč is divided by the Klučov Horst into two basins, the Třebíč Basin in the north and the Moravské Budějovice Basin in the south. In the southernmost part of the Třebíč Basin, at the flat surface between the Jihlava River and the Klučov Horst, gravels of a different age can be found. These fluvial paleo-gravels are related to a different stages and directions of paleo-drainage, according to a changing position of the Alpine-Carpathian Fore-deep in the time of Alpine Orogeny in the Miocene (Hrádek, 1997). In the Early Miocene (Eggenburg) southern direction of drainage is supposed towards to Fore-deep which was oriented in

direction E-W, analogous to the upper reaches of the Želetavka River or the Moravská Dyje River. Later, in the Early Badenian, due to the Fore-deep turning around the corner of the Bohemian Massif to the north (Seifert, 1992) the drainage direction changed to the southeast and east as present the Jihlava River. In the course of drainage composition of pale-gravels varied as well. The gravels of older phases differ from the younger one. While moldavites are present in both types of gravels, in the older one besides the moldavite pebbles of ferrolite (limonitic sediments) deposited both in lacustrine environ (Koutek, 1964, 1971) and in ferric duricrusts (ferricret), where oxides and hydroxids come from weathered durbachites (Miškovský, 1972) under influence of weathering in warm and wet climate in Tertiary. Typical mineral of local ferrolite is maghemite - ferric oxid (magnetic hematite) and further very resistant rutile, coming from weathered amphibolite.

Moldavite is tektite, natural glass, ejected from the Riess Crater near Nördlingen in Germany after the impact of large meteorite approximately 14.7 million years ago (after Early Badenian). One of the fall fields is in the SE part of the Czech Republic, in area south of Třebíč. From the fall field moldavites have got into fluvial and slope deposits. Moldavites and rests of ferric duricrusts (ferricret) with maghemite and rutile are found in southern part of the Třebíč Massif and its surrounding, south of the Jihlava River Valley. Not in the northern part. South of Třebíč remarkable forested elevation raises, named by Koutek (1964) as the Klučov Horst and delimited by faults - the Klučov fault on the north and the Výčapy fault on the south. The highest hill of the Klučov Horst is Klučovská hora - 595 m. Excavations for water pipes disclosed in the Klučov Horst deposits with gravels of the older drainage stage, containing beside moldavites pebbles of ferrolite with maghemite and rutile, demonstrating drainage to the south. It means that the Paleo-Jihlava river has passed through zone of the Klučov Horst from the Třebíč Basin to the Moravské Budějovice Basin. Rests of mentioned gravels have been found, e.g. at Mikulovice.

In the upper part of the Klučov Horst fragments of ferric duricrust have been also found, e.g. at foot of Klučovská hora or Hošťanka Hill, as a rests of original tabular blocs of sandstone or conglomerate. According to Miškovský (1972) ferric duricrust originated by durbachite weathering, Koutek (1964, 1971) supposed Neogene lacustrine origin. Very important finding is that fragments of the ferric duricrusts and rests of lacustrine sediments originated primary in depressions, i.e. in the lowest place of original earth surface and now, at present, they lies in the highest places of ridge.

Uplift of the Klučov Horst did not originated by relative movement on the planes of mentioned faults but it had much more character of the slow diapiric uplift (Hrádek, 1997). Along opened fractures of the Klučov and Výčapy faults intrusion of less dense leucocratic turmaline granite took place. The light granite is exposed in some small quarries and will be visited during excursion. In context of the Klučov Horst diapiric origin there is a very remarkable finding of view point change from the site of the church at Horní Újezd (see excursion site 7).

Existence of ferric duricrust and paleo-gravels with moldavites of the older drainage stage of southern direction demonstrate that age of the Klučov Horst is younger than 15 Ma. Age of leucocratic turmaline granite is Late Variscan, i.e. c. 230 Ma. Up to the time of moldavite tektites fall the Klučov Horst did not exit. It appears from this that diapiric uplift of the Klučov Horst has relations to the Post-Badenian domal uplifts of peri-orogenic zone of the south-east margin of the Bohemian Massif (Hrádek, 1998).

Excursion sites and routes:

1. **Route from Třebíč to Vladislav** lead along deepened valley of the Jihlava River based on the Třebíč fault. The valley is about 70 m deep. On the left side of the valley there are a number of natural outcrops and small quarries exposing durbachite of the Třebíč Massif. On the rock walls durbachite with fenocrysts of potassium feldspar (orthoclase) is well seen.
2. **View point in eastern vicinity of Vladislav.** From this point rectilinear course of Jihlava R., valley in E-W direction is well-visible. This valley has symmetric form and separates the Třebíč Basin on southern and northern parts. Finding sites of the Jihlava River paleo-gravels belonging to younger drainage stage with moldavites are situated at the right valley side (very often closely above upper valley edge). On the left side of the Jihlava River Valley similar gravels have never been found.
3. **Route from Vladislav to Střítež** with views of southern part of the Třebíč Basin. In this area built by durbachites of the Třebíč pluton a number of finding sites of gravels with moldavites of both paleo-Jihlava stages exist. Southern part of the Třebíč Basin is limited by the Klučov Horst with the highest hill Klučovská hora 595 m.
4. **Route from Střítež in Třebíč Basin to Mikulovice at Klučov Horst.** Route leads through village Slavice with well known finding sites of moldavites and gravels of older drainage stage with pebles of ferritic duricrusts, with maghemite and rutile in its vicinity. The hill slopes of Klučov Horst are quite slow.
5. **Mikulovice.** On the horst hill slopes and in places near saddle on the ridge at village gravels with moldavites and fragments of ferritic duricrust (ferrolite) have been found evidencing drainage of paleo-Jihlava to the south. The Klučov fault with intruded fractures and filled in with less dense granite is running closely to the north of the village.
6. **Route from Mikulovice to Horní Újezd.** During this way slowly undulated topography of the Klučov Horst is well visible. Terrain elevations are built by veins of granites.
7. **Horní Újezd.** The site situated in south-western part of the Klučov Horst at the church. Near the church (around 500 m a.s.l.) small quarry exposing leucocratic turmaline granite is situated. The granite intrudes fractures of the Výčapy Fault. Idea of less dense granite penetration to the surface and diapiric uplift could be supported by report about change of view from this site (Novák, 1935). About the year 1880 only the "tiered spire" of church in Moravské Budějovice (site of the church around 465 m a.s.l.) was visible. In the next years it seemed that the church tower crop up and in the year 1930 the whole church tower has been seen together with the roof of neighbouring gymnasium (the whole church is 49.9m high). Situation recorded in 1930 has been confirmed in the nineties of the last century (Hrádek, 1997) but truth of mentioned historical report has not yet been affirmed.
8. **Route from Horní Újezd to Výčapy** leads along southern foot of the Klučov Horst with forested the Černý kopec Hill 537 m, situated on the line of the Výčapy fault.
9. **Výčapy.** Subject of interest is small quarry east from village and near south foot of ridge in the line of the Výčapy Fault. On the quarry wall penetrating of light turmaline granite among blocs of denser and dark durbachite is well seen. Blocks of durbachite are floating in environ of light granite. Ascertained situation in quarry is in agreement with idea of diapirism *as modus vivendi* of the Klučov Horst origin.

10. **Site Pod Hošťankou** (540 m) north of Výčapy. This site lies on the top of the Klučov Horst, at foot of hill Hošťanka (573 m). In this site exist possibility to find fragments of ferric duricrust (ferolite) lying on the ground which contain oxidic and hydroxidic maghemite marking original position in depression

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