Influence of train-generated vibrations on embankment

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Roads and railway lines are often constructed on different geotechnical structures such as tunnels, cuttings and/or embankments. Three main parts are necessary to take into account to evaluate vibration; it means – source of vibrations, vibration propagation path and receiver of signal. This paper describes review of influence of train-generated vibrations on embankment and building in the surroundings. First presented case study documents interpretation of seismic signal in frequency domain using wavelet transform. Example of numerical model on the FEM method (the MIDAS GTS software) shows vertical displacement of the embankment body during movement of train.

Measurement, Interpretation, Evaluation of Vibration: Case Study

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Design for earthquake resistance of structures is described in Eurocode 8. Monitoring of natural or technical (artificial and triggered) vibrations is a standard requirement for management of construction sites. Vibrations vary in periodicity, duration, time and location of occurrence etc. The intensity of vibrations depends on many parameters, first of all local geology, subsurface layers, type of source, prevailing source frequency, parameters of influenced structure … Significant diversity of sources influencing the intensity of a seismic event on the surface, is the reason why sufficiently credible results cannot be obtained and simple relations cannot be derived without a substantial number of seismic measurements. The acquired waveforms need to be interpreted both in amplitude and frequency domains. General assessments of the impact of vibrations on structures are based on international standards for vibration assessment; many countries also specify maximum permissible values in their national standards.

Interpretation of spatiotemporal gravity changes of the 2004–2005 Tenerife (Canary Islands) unrest using the Growth inversion approach

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We revise the interpretation of the observed spatiotemporal (time-lapse) gravity changes accompanying the 2004–2005 unrest on Tenerife by applying the Growth inversion approach based on free geometry model exploration and growing source bodies. By selecting various combinations of the values of the freely adjustable inversion parameters, the Growth approach can produce a suite of inversion solutions (models) that are admissible in terms of gravity data fit. To choose the most realistic solution, additional constraining information must be applied, including the structural controls of the volcanic edifice and its wider crustal environment. The structural subsurface density model plays a key role in our understanding of these controls. We use a 3D density model of Tenerife obtained by inverting the complete Bouguer anomalies (CBA data) again using the Growth approach. The density model sheds light on possible magma ascent pathways through the interpreted permeable structures. Our interpretation of the unrest as a failed eruption, a stalled magma intrusion, is also constrained by the seismic unrest data. We interpret the unrest as hybrid, in which the magma intruded from greater depths (below 8 km b.s.l.) into the central part of the island just north of the Teide–Pico Viejo twin stratovolcanoes. The stalled intrusion released volatiles that disturbed the aquifer at the SW of the caldera rim. This gravimetric picture of the unrest provides new insights into the potential future reactivation of the volcanic system and its environmental impacts.

Developments of archaeomagnetic field transformations by means of higher derivatives evaluation

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In archaeogeophysics, high definition magnetometry is one of the most important acquisition methods. This is due to its high acquisition velocity and high data sampling rate. During the high definition magnetometric datasets interpretation it is very important to recognize and emphasize low-amplitude anomalies from archaeological objects and natural sources (geological and soil structures). Among the recognition of low-amplitude anomalies an important role is played by edge mappers, which are based on higher derivatives (enhances derivatives filters), numerically computed from the originally acquired magnetic field (or gradient). Majority of enhanced derivatives methods are based on the evaluation of various ratios of derivatives of different kind – mostly horizontal and total derivatives and their components. During the numerical evaluation of derivatives it is important to smooth them properly, because these have the tendency to emphasize errors and noise from the original data (in the term of mathematical physics called as instable or incorrect problem). In our department the concept of so called regularized derivatives was introduced and is widely applied. In this contribution, we try to show properties of different enhanced derivatives filters on various archaeomagnetic datasets and suggest the best of them for future application. The mostly used transformations are: vertical and horizontal gradient, tilt angle and balanced horizontal gradient (TDX), theta transformation and so called TDXAS transformation. These methods can not directly distinguish between anomalies of anthropogenic and natural (geology, soil) origin of interpreted anomalies, but can contribute to its joint qualitative and quantitative interpretation.

Possibilities of vertical gravity gradiometry in archaeogeophysical applications

Pašteka R., Zahorec P., Papčo J.

Measurement of vertical gradients of gravity acceleration is not new in geophysics, it was performed by many geophysicists before. In the traditional form it is performed by means of the measurement of gravity acceleration by relative gravity meters on two vertical positions, commonly separated more than one meter away. Such an acquisition procedure is very time consuming, but can bring more detailed results, when compared with the classical gravimetry.

In this kind of survey, it is very important to remove correctly the gravitational attraction from surrounding topography and buildings. Thanks to the state of the art geodetic method and numerical solutions this fundamental processing step can be performed with sufficient precision. The main target is in the majority of cases the detection of subsurface voids, but there is a potential for various other applications, where different density inhomogeneities in the subsurface are searched. In this presentation we give one practical example from void (crypt) detection, but show also synthetic models from other potential applications of vertical gravity gradiometry in archaeogeophysical applications.

Ground vibration measurement and seismic events detection using the MEMS sensors and Raspberry Pi micro-computer and Raspberryshake systems.

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In this work a new electronic system designed to record ground acceleration is described. The system consists of the Micro Electro Mechanical System (MEMS) sensors and very popular micro-computer Raspberry Pi. The network, which was built in such a way, has several virtue points:

1. The system has the highest possible signal-to-noise ratio,
2. The signal can be transmitted via Raspberry Pi interfaces, even if the maximal possible sampling rate is used,
3. Simple Python scripts can be used to process the data and visualize results,
4. Several existing external Linux Nooble mathematical libraries and functions can be easily implemented in data processing,
5. The system is fully remote-controlled using Internet connection and terminal actions,
6. The signals recorded by the system can be clearly visible on a local OLED screen.

Different MEMS sensors have a noise level between 7 and 45 ug. Used in this project the ADXL356 system has the noise 20 ug and is ready to record acceleration up to 2g. In such conditions, the dynamic range of the system is about 100 dB, which means the AC converter

resolution should be 15 bits. Here, the 15 bits resolution was obtained using 12 bits AC converter and signal conditioner with additional gain regulation.

The modules used in the system have additional features. The MCP23017 component adds 16 input/output digital pins, the MCP3208 has eight 12-bits analog inputs, MCP4822 has two 12-bits analog outputs. The additional DS1307 component adds the real time clock (RTC), which can be powered using CR2032 battery. Even though only one Expander Pi can be connected with the microcomputer, another type of expander can be also used.

System specification:

- Power: 4,5 V - 5,5 V
- 16 I/O digital pins: MCP23017
- 8 channels 12-bits A/C converter: MCP3208
- 2 channels 12-bits C/A converter: MCP4822
- RTC clock: DS1307
- Internal reference voltage: up to 4,096 V
- External reference voltage: up to 5 V
- External power supply with insulation: 5 V
- Communication controllers: I2C (0x20) and SPI
- Pin current: 25 mA
- The whole maximal current: 125 mA

Since the ADXL356 MEMS is characterized by a flat response in about 1.6 kHz, the system should has the sampling rate at least 3.2 kHz/channel. Fortunately, using the Raspberry Pi4 with 16GHz processor, we can have the sampling rate even about 10 kHz/channel. Such a rate can be obtained with oversampling, just to have a good visualization on the screen.

Geochemical, geophysical and historical research in the area of the former drainage gallery (built since 1529 by the Turzon brothers) of the lead ore mine in Jaworzno-Dlugoszyn (Southern Poland)

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Since the Middle Ages lead was a significant raw material used for the production of silver from copper ores, but it also had many other applications. In the 15th and 16th century lead was imported to Slovakia from deposits in the region of Olkusz and Jaworzno. High demand for this raw material in Slovak smelters e.g. in Banská Bystrica was covered by import from Poland. Therefore, investments in Polish lead mines (on the basis of the contracts with the bishops of Cracow) were financed in the first half of the 16th century by Turzon brothers from the Spiš region.

The exact course of the drainage gallery, built from 1529, was not known. Analyses of terrain morphology using geodetic and Lidar methods, as well as geophysical and geochemical studies made it possible to identify the location of the watercourse draining the former gallery. The results of geo-electrical surveys and analysis of historical sources made it possible to identify the location of the water outflow from the former drainage gallery. Deep excavations were made in the place of the anomaly identified by geophysical methods in order to identify the lithological profile of the layers.

Deep excavations made it possible to collect samples for geochemical (AAS) and mineralogical studies. Microscopic analysis (SEM/EDS) of sediments from different layers of the historic watercourse confirmed the presence of oxidized metal-bearing minerals containing Zn (up to 1708 ppm), Pb (up to 543 ppm), Fe (2.78%), Mn (1093 ppm), Ag (up to 1973 ppb) in their structure.

Gravity Modelling of the Lithospheric Contact of the Western Carpathians and the Bohemian Massif along the CEL09 Profile. *(poster)*

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CEL09, one of the CELEBRATION 2000 profiles, crosses two of the most important tectonic units in the Central Europe – the Bohemian Massif and the Western Carpathians. The two represent complex lithospheric-scale geological structures and their contact zone is still a subject to discussion. In this study, the contact zone, and the lithospheric structure along the CEL09 profile was analysed by 2D gravity modelling using the new AlpArray gravity data and was constrained by seismic wide-angle reflection and refraction results. Densities of anomalous bodies were defined by the transformation of the modelled P-wave velocities. A good correlation between density and seismic models was shown. The resultant 2D density lithospheric model consists of the five principal layers: sediments, upper crust, lower crust, lower lithosphere, and asthenosphere. In general, sediments are characterized by values from 2.30 to 2.51 g·cm^{-3}. The non-sedimentary upper crust is split into two layers with the upper part divided into various density inhomegeneities reflecting the gravity effects of the specific geological structures. Densities vary from 2.60 to 2.79 g·cm^{-3} in the Bohemian Massif, and from 2.60 to 2.74 g·cm^{-3} in the Western Carpathians. The lower part of the upper crust is significantly more homogeneous compared to the upper part (2.78-2.80 g·cm^{-3}). Five different sectors of the lower crust resulted from this density model, with the first sector (Saxothuringian) consisting of two separate layers (2.85 g·cm^{-3} in the upper part, 3.12 g·cm^{-3} in the lower). The Moldanubian lower crust is characterized by the density of 2.98 g cm^{-3}. The Moravo-Silesian lower crust dipping under the Carpathians Foredeep and the External Western Carpathians have a density of 2.97 g cm^{-3}. The Western Carpathian-Pannonian region is represented by slightly lower density of 2.94-2.96 g cm^{-3} compared to the Bohemian Massif. In general, the model shows the difference between the older, cooler, and thicker Bohemian Massif (in average: ~32 km thick crust, and ~120 km thick lithosphere), and the younger, warmer, and thinner Carpathian-Pannonian region (~28 km crust, ~95 km lithosphere). The detected contact is delimited by a change in the Moho and the LAB topography and assumes an overthrusting of the Western Carpathians onto the Bohemian Massif by ~30 km resulting in a neo-transformation of the crust/mantle and related lithosphere after subduction.

H/V spectral ratios of rotational and translational signals: dependence of site effect parameter values on the sensors deploying.

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The research concerned horizontal-to-vertical (H/V) spectral ratios calculation for rotational and translational signals that two seismic stations registered. At first, called Imielin (IMI), the sensors were deployed in the technical venue. The second place, called Ziemowit (ZIE), assumed the situation of the sensors mounting on the ground floor of the small building. The distance between the stations reached up to 10 meters. Each of them collected 45 signals of the same as a result of mining-induced events. H/V curves were estimated using the two approaches: the Fourier amplitude Spectrum Analysis (FSA) and the Response Spectrum Analysis (RSA). The H/V ratio obtained from the RSA assuming calculation with changing damping factors as follow: 1%; 3%; 5%; 7%; and 9%, while in the case of the FSA, the ordinary approach was considered. The main aim of the study concerned on the comparison of estimated site effects, obtained by two different spectral approaches, for rotational and translational data, which were registered at close distances but in different conditions of the deployment of the sensor. Additionally, the impact of the damping factor on the site effect parameter was investigated.

The FSA approach produced similar ratio curves of the translational motion, while in the case of the RSA, the amplification increased for the data from the building. In contrast, the resonance frequency was almost similar, and the influence of the damping factor values was not observed. The rotational resonance frequency obtained from the FSA approach produced similar values for the highest amplification peak. Still, in the case of the registration from the ground floor of the building, additional amplification peaks before the highest one were generated. Comparison to the RSA results showed that the frequency of the additional peak estimated from the FSA could be distinguished as a resonance frequency. Therefore, the results suggested that the rotational resonance frequency can be affected by the ground floor dimension. In consequence is characterized by lower values that were not noticed in the translational motion analysis.

Surface mapping of underground mining corridors with the use of soil radon emanometry. *(poster)*

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The Čáry location is significant for the underground mining of lignite which is actively happening to this day, which is the reason why a part of this area is undermined. The original aim of the emanometric measurement was to distinguish the undermined and non-undermined parts of the measured location. It was presumed that the radon concentrations would be relatively low with minimal variability and during the transition from one area to the other the values would not fluctuate, but they would keep a certain stable character. However, the emanometric results were unexpected, since the values did not change during the transition from one area to the other, but increased radon concentrations were remarkable and also correlated well with the plan of the mine which described the locations of individual underground corridors and mined spaces.

Geoelectrical modelling of Dobrá Voda seismoactive area. ***(poster)***

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In this study we present geoelectrical modelling of the Dobrá Voda area based on data from magnetotelluric measurements. This area is well known for its increased seismic activity, which may be related to its location at the contact of the Bohemian Massif, the Eastern Alps, and the Western Carpathians. Their mutual movement creates tensions that cause seismic activity. Using this method, we tried to capture the tectonic structure of the Dobrá Voda area, which can help us to understand its evolution and processes that preceded earthquakes. Magnetotelluric data were collected at 8 sites distributed along profile with northwest-southeast orientation. Target penetration depth was at least 10 km. We modelled the data in the WinGLink software by 2D inversion code, and calculated 2D conductivity models of regional structures. The best fit between measured and modelled data was estimated by changing the settings of several inversion parameters during the inversion process. The presented geoelectrical model shows image of the main conductive contrasting tectonic structures in the studied area, and it is used for geological interpretation. In the future, we plan to supplement the geoelectrical models with results of seismic measurements.

The latest studies of the lithosphere in Slovakia based on the magnetotelluric models.

Vozár J., Bezák V.

UVZ SAV Bratislava

The presentation shows lithosphere studies obtained within the project APVV-16-0482 in the last five years. The main method was magnetotellurics (MT) providing conductivity models of structures, which was combined with other geophysical methods. The research was conducted in three areas:

a) Structures at the contact of the Outer and Inner Carpathians

In a series of works, we focused on 2D and 3D MT modelling on profiles across the Klippen Belt (KB), and the goal of the studies was to compare the deeper structures of the KB in its western and eastern sections. In the western section the tectonics is dominated by the Flysch Belt (FB) overthrusts onto the KB. On the other hand in the eastern section the situation is opposite, where the KB is thrusted on the FB. By later processes the southern part of KB is cut off by steep faults. The contrasting tectonic style of the western and eastern sections of KB reflects the different kinematics of the Inner Western Carpathians (IWC) and the European Platform (EP) collision in the western and eastern parts. While in the western part the transpression tectonics dominated, in the eastern part there were frontal thrusts on the EP. Only then the transpression movements along the BP begin.

b) Interpretation of MT measurements along the seismic profile 2T

From north to south the 2T profile crosses all the basic tectonic units of the Outer and Inner Carpathians, and in addition to seismics, gravimetric and geothermal data were modelled on the section. Compared to the 2D model, the 3D MT model gives qualitatively new information about the physical properties of the crust along the profile and in its immediate vicinity. The new phenomena are highlighted in the 3D image, such as whole crustal conductivity zones at the boundary of physically contrasting blocks, namely the Carpathian conductivity zone (CCZ), the Pohorelá shear zone and the Zdychava fault zone. We see a significant difference especially in the case of the interpreted CCZ, which was not visible in the 2D section. On the contrary, in the sections through 3D model the CCZ is clearly visible and we assume that it reflects significant fault zones at the EP-IWC junction.

c) Preliminary MT models in eastern Slovakia

On all three profiles that we have chosen, we focused on whole crust structures and therefore the profiles resolution is insufficient for shallow geological details. The dominant feature are the mostly middle-crust wide conductive zones, which are revealed on all profiles, although not always in the same position. Such structures have no equivalent in other profiles in central (2T) or western (MT-15) Slovakia, only with the exception of the southern part of the 2T profile, where it was interpreted as a young alternated crust by volcanic activity or hydrothermal fluids. The conductive zones on our three profiles are also genetically young and we associate them with Neoalpine tectonic processes in the Neogene.

Microgravimetry and GPR: Searching for Archaeological Objects in St. Joseph Church in Beckov, Slovakia *(poster)*

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The combination of two geophysical methods - microgravimetry and GPR (ground penetrating radar) - has been proven to be very capable and effective tool for archaeological prospection. The methods have been used multiple times in momentous buildings in the last years and they have demonstrated an effective measurement and reliable results. The combination was chosen to seek underground spaces of St. Joseph Church in Beckov, Slovakia. Measurements were performed during a two-day survey in order to confirm the existence of the presumed crypts and their entrances, which, according to historical documents, should be located under the church floor. This contribution presents compelling results of the survey and subsequent inverse modelling of the objects in the selected area under the church altar. The cavities have not been verified yet.

The first pan-Alpine unified Bouguer anomaly map

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The European AlpArray initiative was established to improve our understanding of the geological development and the seismic risk in the Alps-Apennines-Carpathians-Dinarides mountain system. As part of this project, the AlpArray Gravity Research Group (AAGRG) was established, the aim of which was to compile a homogeneous gravity data set in the wider Alpine region. The published map of complete Bouguer anomalies of the wider Alpine region is homogeneous for the first time and compiled according to state-of-the-art criteria in terms of input data sets, applied methods and all corrections of the measured gravity acceleration (topography, bathymetry, atmosphere, special emphasis was placed on the gravitational effect of large mountain lakes, which are located in the studied area). The resolution of gravity anomalies is appropriate and fully sufficient for integrated modelling of local, regional to continental geological structure of the European lithosphere, as well as for its joint inversion with other, especially seismic data sets.

Examples of Benioff strain release in mines

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The study concerns the Benioff strain release (BSR) method for mining seismicity observation. Methods analysing Benioff strain release or seismic moment release are widely used in natural seismicity. Especially, the BSR method and similar are applied to predict the size and occurrence time of the strong seismic event based on the critical-to-point model. Moreover, these methods analyse acceleration-like or quiescence-like behaviour. The type of release can indicate what actually appeared in the rock mass. Following the previous study on natural seismicity, the research focused on the adoption of the BSR method for seismicity related to a mining operation.

The preliminary observation indicated the patterns repeating for different longwall panels. Moreover, the BSR distinguishes easily the changes in energy release caused by varying mining conditions and geological settings. Correlation of acceleration-like or quiescence-like trends with varying conditions showed that analysis of the trends can be used as a tool the assess the significant changes in the rock mass, as well as, in the seismic hazard.

Due to the development of the BSR method for natural seismicity, new approaches have appeared. An interesting methodology was shown for the technique of the revised-BSR which uses an attenuation function. This function limits the influence of far-away preshock events and only near-distant events lead to the nucleation of a strong event. Such an approach was also implemented for mining data, which reveals that the nucleation radius in a mine can be smaller than the longwall panel width or similar in size.

The study of fracturing using seismic methods supported by forward modelling – a field case (Strzegom and Podleśna, Poland)

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Fracturing represents the existence of discontinuities and weakening surfaces in a rock structure that exceed the dimensions of the mineral grains forming the rock. Cracks in rocks occur more frequently as crack systems with specified orientations than randomly oriented features. Thus, it has been observed that anisotropy of elastic properties of the massif causes the prioritisation of cracking in specific directions. It is not always possible to measure cracks directly in a quarry, hence the need to use seismic methods that allow for the identification of main crack systems.

This paper presents seismic refraction and multichannel analysis of surface wave measurements used to study the anisotropy of P- and S-wave velocities. Additionally, synthetic forward modelling is presented as a tool for supporting seismic anisotropy studies. The geophysical measurements of cracks allowed for the analysis of the fracturing of a granite rock mass in a Paleozoic granite quarry (Strzegom, Poland) and the fracturing of dolomite from a Triassic dolomite quarry (Podleśna, Poland). By applying forward modelling to support multichannel analysis of surface waves (MASW) and refraction studies, this method simplified data processing and verified the final results based on data from difficult seismic conditions.

Selected geophysical methods as tools for identifying the location of the Sztolnia Ponikowska in Olkusz, Poland

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The analysis of archival materials, notes and historical mining maps, despite providing valuable information, often does not allow to clearly determine the location of old excavations existing for hundreds of years. Nevertheless, after many years, an inventory of abandoned workings is often carried out. However, drilling boreholes to detect and locate pits lying shallow below the ground surface is uneconomical. Therefore, geophysical methods are effective techniques that help solving such problems.

The research object is the historic adit Sztolnia Ponikowska in Bolesław (Olkusz district, Poland). The adit was built in the years 1563–1621, and its purpose was to drain water from lead ore mines in Olkusz. The flood of the river in 1703 caused severe damage to the adit, as a result, around 1712, it ceased to function as the last drainage adit in the Olkusz

area. At the beginning of the 20th century, the lack of the adit conservation resulted in the loss of water flow capacity and, as a result, its complete disappearance.

The presented research attempts to select the best geophysical method to detect the location of the Sztolnia Ponikowska. Three geophysical methods: electrical resistivity tomography ERT, seismic refraction tomography SRT and multichannel analysis of surface waves MASW were selected, and their suitability for this type of research was tested. Preliminary results showed the changes in geophysical parameters i.e. resistivity, P- and S-wave velocities, as well as, dynamic elastic modules corresponding to lithological and mining properties.

Imaging summit structures of Mt. Etna Volcano by forward density modelling. *(poster)*

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Stratovolcano Etna is the largest active volcano in Europe, well-known for its continuous, mostly effusive eruptive activity. It is located on the east coast of Sicily (Italy) north of Catania city. New gravity survey was undertaken in July 2021 to investigate the subsurface of the Etna's summit area. Only the NW part of the planned survey area was accessible to field work due to ongoing intense eruptions. The gravity stations (171 in total) were positioned using precise geodetic positioning based on GNSS technology. The gravity data was processed in a standard manner applying all corrections necessary for the calculation of complete Bouguer anomalies (CBA). Special attention was paid to the computation of precise topographic correction using the Toposk software. As the topography around the summit

craters may change significantly in short time due to Etna's activity it was a quite challenging task. The reference density of 2300 kg/m3 was used in the calculation of the CBA and in the 3D density modelling too. The Bouguer anomaly map shows dominant gravity low indicating the presence of low-density material below summit craters. We use forward density modelling and the IGMAS+ (Interactive Geophysical Modelling Assistant) software to depict the subsurface structures in the investigated area. We assume homogeneous density distribution in modelled geological formations. To constrain the 3D density model we use existing geological and volcanological data. The NE edge of the surveyed area crosses the Pizzi Deneri zone that is characterized by a high concentration of faults and eruptive fissures. The presence of these structures could result in lowering the local density, thus explaining the gravity decrease observed at the northern edge of the Bouguer anomaly map. Presented model has confirmed the double conduit feeding system below the summit craters surrounded by highly weathered and fumarolized volcanics. It represents though simplified, yet geologically plausible insight into upper 2 kilometres of the Etna's subsurface.

Lithospheric structure and its rheological properties in the carpathian-pannonian area, calculated using 2D integrated modelling method. *(poster)*

Dérerová J., Bielik M., Makarenko I., Kohút I., Legostaeva O., Godová Dominika, Savchenko O., Starostenko V., Zeyen H.

The Carpathian-Pannonian–European platform area with its geological complexity provides a great opportunity to study the structure of the lithosphere, the asthenospheric and lithospheric processes taking place within it and their mutual interaction during the continental collision, the orogeny, the volcanic arc and related fore-arc and back-arc basin development. Unlike most other methods that focus on interpretation of individual geophysical fields, we utilize 2D integrated modelling approach to determine the lithospheric structure and its rheological properties. This method combines joint interpretation of gravity anomalies, topographic heights, geoidal heights and surface heat flow data. Based on the calculated temperature

distribution and given rheological parameters of the rocks, we can construct a simple rheological model of the lithosphere.

2D integrated modelling method has already been used to estimate the lithospheric structure along several transects passing through the Western and Eastern Carpathians and the Pannonian Basin. Based on the results, a map of lithospheric thickness has been constructed and published. Continuously, new transects are being added and interpreted, with lithospheric thickness map being updated. In this presentation, we focus on modelling along several new transects, namely transect HT-1 running through the Western Carpathians and passing through the High Tatras, and transect Vyhne running through the western part of the Western Carpathians and passing through the location of Vyhne tidal station. Rheological modelling focuses on Vyhne transect and transect VII located in the Eastern Carpathians.

Taking into account all obtained results, we can summarize that lithospheric thickness in the carpathian-pannonian region increases from the youngest and hottest tectonic units (the Pannonian Back-arc Basin system) to the oldest and coolest ones (the European Platform). While in the western part of Western Carpathians the lithosphere is almost flat (100 km depth), in the central and eastern part of the Western Carpathians we observe thickening of the lithosphere up to 110-140 km and formation of lithospheric root. Lithospheric thickening is accompanied by crustal thickening. The thickening continues in the Eastern Carpathians with observed values up to 200-240 km, with the most pronounced lithospheric root in the Vrancea zone. Rheological models indicate that different tectonic units show different rheological behavior. Generally, lithospheric strength in compressional mode is higher than in extensional and the largest strength is located on the boundary between upper and lower crust. Maxima of strength can be observed in the European Platform, in the Western Carpathians and in the Inner and Outer Eastern Carpathians.

Application of georadar as a tool for analysis of road construction layers and inspection of bridges. *(poster)*

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Georadarové vlny majú schopnosť preniknúť do asfaltových a betónových vozoviek a získať tak neoceniteľné informácie o stave jednotlivých konštrukčných vrstiev vozovky ako aj o stave podkladovej vrstvy. Z výsledkov merania získame neoceniteľné informácie, ktoré sú nevyhnutné pre efektívne plánovanie opráv a správy ciest a mostných konštrukcii. Georadarové meranie poskytuje súvislý podpovrchový rez - radargram pod meranou cestnou komunikáciou v jemnom intervale vzorkovania na vymedzenie vrchnej časti vozovky a hrúbky jednotlivých asfaltových a podkladových vrstiev. Pri meraní na mostných konštrukciách vieme získať presné informácie o umiestnení výstuže, dilatácie, torzných lán ako aj o stave a hrúbke betónu. Obrovská výhoda je, že všetky tieto informácie vieme dostať nedeštruktívnym spôsobom. Pri pravidelnom a opakovanom meraní georadarom sa vieme sústrediť na anomálne oblasti, ktoré môžu byť v budúcnosti problematické a tak prechádzať deformáciám a haváriám vozoviek a mostov.

Synthetic modelling of the “muons-chamber” in the Great Pyramid: could high-precision microgravimetry also map the chamber? *(poster)*

Pašteka R., Zahorec P., Papčo J., Mrlina J., Götze H.-J., Schmidt S.

In this presented study we have investigated the question as to whether highly accurate microgravimetric measurements on the side of a pyramid could also map the recently discovered "muon chamber" in the Great Pyramid of Giza in Egypt. Exploiting the technical capabilities of modern gravimeters, we performed three-dimensional model calculations with realistic model parameters obtained from published literature. Under ideal experimental conditions researchers are able to measure relatively small gravity effects around -1×10-7 ms-2. However, to transfer the model scenario to investigating the real-world pyramid chamber we need to know what the chamber may contain – such knowledge can help in estimating a more realistic result.

ZInv – Modern tool for potential fields inversion

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Interpretation and inversion of microgravity anomalies belong to important tasks of near-surface geophysics, mostly in cavities detection in engineering, environmental and archaeological applications. One of the most used concepts of inversion in applied gravimetry is based on the approximation of the model space utilizing 2D or 3D elementary sources to estimate their densities by means of the solution of a corresponding linear equation system. There were published several approaches trying to obtain correct and realistic results, which describe real parameters of the sources. In the proposed contribution, we introduced new modern software for inversion called zInv programmed in C#. The software offers focusing inversion in terms of selection of different stabilizing functionals, mesh inspection and forward modelling of potential fields as well. The visualization of results is either in form of 2D slices or 3D iso-slices and iso-surfaces. For demonstration, we decided to use one synthetic model and one real-world dataset (microgravity data from St. Nicholas church in Trnava). Results have shown that algorithms can generate satisfactory model results, from which we can describe real geometry, dimensions and physical properties of interpreted cavities.

Correlation of deep seismic cross-sections with new borehole data: firsts results from Čizatice geothermal aquifer

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The East Slovakian basin, is an example of a geothermal structure with a linear directed heat flow ranging from 90 to 100 mW/m2 from west to east. The west rim of the basin is divided into two geothermal structures (Cizatice and Durkov), wherein Cizatice was realized geothermal borehole with a total depth 2703 m. The borehole localization was hing on the interpretation of several deep seismic sections. The new borehole data confirm our assumption of existence by several tectono-geological factors, like as: (a) tectonics, and the associated disintegration of the aquifer block by multiple deformations during the pre-Paleogene mainly Miocene period. (b) hydrogeological, the geothermal structure is accommodated by Na-Cl waters with 32,1 g.l-1 mineralization. The chemical composition of the water is influenced by the Middle Triassic dolomite aquifer as well as by the infiltration of saline solutions. (c) geothermally anomalous heat flow of 123,6 degrees with 13,8 l/s total flow near the Slanské vchy volcanic chain seems to be the perspective for heat production.

Some remarks on geophysical study of the Carpathian-Pannonian lithospheric structure - review

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Despite the great efforts of geologists and geophysicists, many questions concerning the deep structure, composition, and tectonics of the lithosphere in the Carpathian-Pannonian region and its surrounding geological units remain unanswered. The contribution deals with the most prominent features of the complete Bouguer anomalies and the lithospheric thickness in the Carpathian-Pannonian region. The stripped gravity map as well as the modelling of gravity data were used to re-evaluate the sources of the most important gravity anomalies. The Carpathian gravity low was divided into three sub-lows: the Western, Eastern and Southern Carpathian gravity lows. The Western Carpathian gravity low consists of the External and Internal Western Carpathian gravity lows, whose causes are different. The source of the External Western Carpathian gravity low is the low-density sediments of the External Western Carpathians and the Foredeep, while Internal Western Carpathian gravity low can be explained by the upper crustal deficit mass, which is formed by the rocks of the Tatricum and Veporicum. The main sources of the Eastern and Southern Carpathian gravity lows are crustal roots, whose gravity effects together with the gravity effects of surface sediments of the External Carpathians and the Foredeep form the observed gravity anomalies over both orogens. The Pannonian gravity high is caused by the expressive Moho elevation. Based on the calculated stripped gravity map several local gravity highs (values >+50 mGal) were recognized. They correlate with the Danube Basin, the Transcarpathian Basin, the Békés Basin and the Makó trough. Their sources are high-density crustal bodies, whose apical parts reach depths of only 7 to 12 km. Finally, the expressive different course of the lithosphere-asthenosphere boundary in the Western and Eastern Carpathians was explained by the different Neo-Alpine development of both orogens. The mantle lithospheric root (of >240 km) in the Eastern Carpathians is a result of a sinking of the upper part of the broken slab during the frontal continental collision. On the contrary, no thickening of the mantle lithosphere was observed in the junction zone of the Western Carpathians and the Bohemian Massif. The typical thickness of the continental lithosphere (~100 km) was explained here by the oblique continental collision. The Pannonian Basin system is characterized by one of the thinnest continental crusts (~25 km) and lithospheres (~75 km) in the world.

Geophysical survey for radioactive waste repositories (Kravi hora site)

Jirků J.

G IMPULS Praha spol. s r.o.

Between 2018 - 2020, seven candidate sites for the potential deep geological repository of nuclear waste were subject of detailed geophysical and geological survey in the Czech Republic. All of them lied either in igneous or metamorphic massifs across the country. In this talk I´m going to introduce results of multi-disciplinary geophysical survey at the Kravi hora site, lying in the eastern part of the Czech Republic in layered metamorphic units of para-gneisses, granulites or migmatites. The Kravi hora site represents a very interesting locality with complicated geological settings. Additionally, its history of a uranium district gives a large number of deep drillholes helping in final interpretation. Results of geophysical methods were cross-correlated with a large data-sets of in-situ geological information (mapping, radiometry).

Estimation of Bouguer density from surface and underground gravity measurements

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In the gravimetric survey, the correct determination of the density of topographic masses (so called Bouguer correction density) is a necessary condition. We present two methods for estimating the mean density of topographic masses based on gravity measurements along with detailed topography modelling using LiDAR data. The first method is based on the analysis of only surface gravity measurements (Free-air anomalies) and the calculated topographic effect. This method can be considered as a modified version of the well-known Nettleton's method.

In addition, we use a second method for verification, combining surface gravity data with gravity measurements directly below the Earth's surface (tunnels, mines, etc.). We compare both methods at different locations in Slovakia, mostly using existing or under construction highway tunnels.

A reliable ERT cross-section based on the measurements with damaged equipment - possible or not possible?

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The ERT recognition was made as a required supplement to the geotechnical works for identifying a shallow subsurface in the post-mining area situated to the south of Katowice City, Poland.

The measurements were made for four, closely located, 160-m-long lines. After the measurements, it turned out that results obtained only for the first of the four lines was acceptable and suitable for interpretation. For sections 2-4 the RMS error obtained was unexpectedly more than ten times higher than for line 1. Due to the close location of the measurement lines, stable weather and field conditions, the only reason it seemed to be the failure of the device. As a result of the tests, it turned out that the reason was damage to one of the multi-core cables during the field works. In this case a re-measurements were not possible due to the ongoing building works. Thus a different techniques were applied to identify readings arising from the damaged parts of the cable. After removing the faulty readings, the results of inversion were compared with that obtained for the first line and with geotechnical cross-sections.

Vikartovce fault recent neotectonic activity monitoring using a combined geodetic approach

Papčo J., Madarás J., Gerhátová Ľ., Janák J., Czikhardt R., Majkráková M., Letko P., Novák A., Kubica L., Oravec L.

Data concerning faults and their parameters is important information for basic geological research as well as for landscape planning, building activities, and assessment of health and natural hazards of the geological environment. Selected faults were mapped and monitored within the WECAFARE project by several geophysical and geologic methods in combination with recent geodetic and remote sensing techniques. Recent surface motion activity of the wider area of the Vikartovce fault and its horizontal and vertical components were also monitored by measurements based on Global Navigation Satellite Systems (GNSS) technology, high-precision measurements of absolute gravity values, high-precision leveling, and satellite radar interferometry (InSAR). This activity of horizontal and vertical movements of the blocks was monitored on the existing leveling network and the InSAR natural persistent scatterer network. These techniques were supplemented by new absolute gravimetric and GNSS measurements at periodically repeating intervals on the newly built integrated geodetic monitoring network VIKART. From the neotectonic activity, it turns out to be a very interesting area of Štrbský prah and Popradská rovina, which together with the area of the sub-Tatra fault shows a slight upward trend.

Geophysical and environmental research of faults of the Western Carpathians

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In the field of both general and applied geological research, faults represent a very important and interesting subject of study. They influence to a great extent the interpretation and understanding of geological structures and restrict the possibilities of land utilization where urbanization and building activities are concerned. Not only they make possible to locate such commodities as underground water aquifers or ore deposits but they also help to describe their migration routes. To determine the exact position of a fault, its space orientation, width and filling is immensely important for tectonics as well as the socio-economic sphere, namely for land planning, building activities, health risk assessment, localization and migration of sources and aquifers. The commonly used fault mapping method which consists in a direct observation can be hardly applied in such covered terrains as the territory of Slovakia mostly is. A possible solution might be to develop an exact multidisciplinary methodology that would combine surface fault mapping with determination of the space continuation of faults in shallow/deep depths using geophysical techniques (DEMP, ERT, VES, VLF, SP, shallow seismics, GRS, AMT, CSAMT), geochemical methods (Rn, CH4, CO2 emanations, mercurometry), and, in the case of larger faults, also the analysis of remote sensing imagery, LiDAR and DTM. The data obtained by applying this method would need to be compared with the results of a structure – tectonic analysis of the studied areas. Apart from a clear definition of procedure and of the most appropriate techniques of field fault mapping, the method would provide a detailed map of local discontinuities with their discovered parameters (thickness, permeability, water saturation, dip and others). In any case, the development of an effective method for surface fault mapping in covered areas is to be approached as a complex issue.

On gravimetric detection of thin elongated sources using the Growth inversion approach: synthetic case studies

Bódi J., Vajda P.*, Camacho A. G., Papčo J., Fernández J.

Thin elongated sources, such as dikes, sills, chimneys, inclined sheets, etc., in volcano gravimetry, or ore bodies in mining applications, pose great challenge to gravity inversion methods based on model exploration of the subsurface partition and growing sources bodies. How the Growth inversion approach can cope with it is the subject of our presented study. We investigate the capability of the Growth inversion to detect (reproduce) thin elongated sources. We use synthetic 3D/4D micro-gravity changes of simulated sources placed in real volcanic environments at three selected volcanic sites. Synthetic gravity in these case studies is forward computed at benchmarks of the existing gravimetric monitoring networks and at a regular fairly dense mesh on the topographic surface. Comparison of inversion results for the benchmark datasets with those for the mesh reveals how much information about the simulated sources is lost by the sparse sampling of the signal in terms of benchmarks.

Our case studies demonstrate the benefits and limitations of the Growth inversion applied to detect thin elongated sources. Sources of small volume and high density contrasts, especially those that are thin and elongated, cannot be detected (reproduced) by Growth realistically. They are imaged (reproduced) as much thicker, much more voluminous (blown up) with much smaller density contrasts. This is due to the fact that the density contrast is not sought in the inversion, but preselected by the user. Moreover, the Growth inversion requires small density contrasts to run properly.

When the Growth procedure runs with small preset density contrast values, it can correctly reproduce several parameters of even thin elongated sources: the location (both horizontal position and depth), the orientation, the longest dimension (length) and relative shape (the type of source body geometry). Other parameters of these source bodies are biased, strongly exaggerated, depending on the preselected density contrast: thickness (the size in one or two dimensions) and volume. However, the anomalous mass, as the product of the determined

volume and the preset density contrast, is determined correctly, which is a key factor in volcano gravimetry or mining applications.

Research of dynamic effects of blasting in the Mníchova Lehota quarry

Pandula B., Kondela J., Fehér, Konček M.

Vibration caused by blasting works is one of the basic problems in quarries, and intense vibrations can cause critical environmental damage near the quarries. Disintegrating the rock mass by blasting works generates seismic waves with different maximum particle velocities and a wide range of frequencies. This process depends mainly on the structural properties of the rocks, charge properties and the blasting technology. It is very important to investigate how to regulate the vibrations caused by blasting works in mitigating the negative effects of the blasting works in quarries. The maximum values of environmental particle vibration velocity depend on a large number of different factors. Using the velocities and frequencies of seismic waves, the optimal millisecond interval was sought to reduce the intensity of the vibrations caused by blasting works on the environment. The experiments confirmed the theoretical assumptions that the greatest decrease in vibration intensity occurs when the seismic waves are in the opposite phase. The results of the experiments were confirmed in practice during the research of blasting works in the quarry Mníchová Lehota.

An open data infrastructure for the study of anthropogenic hazards related to exploitation of georesources as a part of the European Plate Observing System (EPOS).

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The hazards induced by the exploitation of georesources focuses growing interest of both science and industry. Anthropogenic seismicity appears as one of the examples of unwanted technological answers visible in the natural environment caused by humans activities. The socio-economic impact of the induced seismicity is very significant and related to material loss, injuries and even fatalities (e.g. mining rockbursts and tunnels collapses). Unfortunately, the data which are essential to asses and mitigate the associated hazards are often unavailable because of restricted access. To respond to the need of the scientific community the Thematic Core Service Anthropogenic Hazards (TCS AH) has been created within the framework of the European Plate Observing System, a solid earth science European Research Infrastructure Consortium (ERIC). Today, TCS AH is an open consortium of 13 European institutions. TCS AH provides access to a novel e-research infrastructure, the EPISODES Platform to foster both research and training on induced seismicity and geo-hazards related to the exploration and exploitation of geo-resource. The EPISODES Platform is connected to international data nodes which offer open access to multidisciplinary datasets, called episodes. Episodes comprise geoscientific and associated data from industrial activity along with a large set of embedded applications for their efficient data processing, analysis and visualization. The EPISODES Platform opens also the possibility to create new applications and combine implemented applications with the user's codes. This presentation shows the current results of the TCS AH research infrastructure integration and also indicates the benefits of their usage for science and potential industrial partners.

Mapping of hydrocarbon deposits and their alternative use using a graphics system *(poster)*

Čambál J., Wittenberger G., Šofranko M., Konček M., Fehér J.

The paper is focused on the use of electronic clear records of the state of hydrocarbon and geothermal deposits. It clarifies alternative possible uses of extracted - depleted deposits, their other possible uses such as waste storage, installation of heat pumps, after their repair and reconstruction for re-storage of natural gas - underground storage. We will receive information about the drilled wells quickly and clearly by electronic records, resp. probes, liquidated or probes in operation. This also contributes to the safe and trouble-free operation of the probes in operation.

Applications of seismic methods in undergrounf mining research

Budinský V., Kondela J., Pandula B.

Technical University of Kosice

Seismic methods allow a wide range of uses. We can apply them across all geological disciplines, solving environmental problems, building and specially deploying certain types of solutions. This paper shows only a brief overview of the great use of seismic methods. Paper capture the specific use of a typical seismic method for a given problem and its solution. For example, in mining of minerals, seismic can provide valuable information for the overall interpretation of the fracture zones. The aim of this study is to identify the possibilities of searching for Au mineralization of the intermediate-sulphide type, which are located at the deep levels of the historic Rozália mine with metal mineralization near Banská Hodruš. The study focuses on the search for sub-horizontal tectonic structures accompanied by metamorphosis of breccias in andesites, which can be detected as zones from reduced seismic velocities. Due to the limits arising from the field, 2 methods were applied - seismic refraction and seismic tomography.

Fragmentation of rock material in the Trebejov quarry depending on the geometry of the blasting and its timing

Buchla I., Kondela J., Pandula B., Konček M., Hreus S.

The most economical and technologically acceptable technique for dismantling a rock mass at present is the use of blasting. Blasting works are also used in the construction of civic buildings, including the construction of highways, tunnels, underpasses or dams. The operational and cost impacts of blasting operations are significant for mining operations. Ultimately, they affect the entire mining operation from transportation to sale. Fragmentation of the rock mass during mining involves breaking up the rock during blasting into suitable size fractions. This simplifies rock handling, transport and processing. The optimized explosion fragmentation process improves the performance of loaders, transporters and crushers. At the same time, it minimizes their maintenance and repairs. Every shot is a source of positive and negative impacts. On the positive side, the explosion releases a large amount of gases with high pressure, intense heat and energy. This causes the rock mass to crack and disintegrate. Up to 30% of the energy released by the explosion is used to fragment and discard the disconnected material. Unfortunately, sometimes more than 70% of the released energy causes negative effects. Negative effects include air / air overpressure, vibration, noise and dust. It is the negative effects that can endanger human safety and health and damage building structures near the explosion zone.

Noise and vibration in the environment. *(poster)*

Šimo J., Pandula B., Kondela J., Farkašovský R.

The subject of the study is the assessment of the impact of the extension of the wide-gauge line from Košice, through southern Slovakia and Bratislava to the border with Austria. It is a project and intention to build a modern fully electrified sophisticated transport infrastructure, which, thanks to the wider track, enables higher transport speed, its safety, reduced volume of operating noise and technical seismicity. The aim of the study is to assess the vibroacoustic impact of the wide gauge line and its impact on the environment. The study presents the measurement methodology and instruments that were used to measure noise and vibration, potential noise exposure, intensity of seismic shocks, frequency spectrum and the law of attenuation of seismic waves on selected railway sections. Permissible values of noise and vibration in the outdoor environment and vibrations in the indoor environment of buildings are compared with the measured values. The study provides an analysis of noise and vibration on the existing wide-gauge line and also on the planned future route of the wide-gauge line for speeds up to 150 km / h.

GPR Road diagnostics *(poster)*

Grinč M.

The GPR survey of selected roads with built-in dynamic scales, which showed signs of damage or degradation of their nearby zone, were carried out. GPR was the most important method of the survey. The road survey was focused on detection of inhomogeneities, inconsistencies in construction and mapping of road construction layers, which endangered operation of the built-in dynamic scales. To support the GPR survey passportization of visible defects and degradation of the roads and core drilling within the solid layers of the road's construction were also carried out in order to precise the survey. The survey was conducted at seven localities in the border areas of Slovakia. For georadar measurements, a shielded measuring system GS8000 made by Swiss company Proceq was used with an antenna with a variable step-changing frequency of emitted electromagnetic waves from 40 MHz to 3440 MHz. By using a wide range of frequencies, the system can achieve excellent resolution right

from the surface up to the manufacturer's maximum survey depth of 10 m. In this case, a measuring step of 0.01 m was used. The GS8000 produces two types of radargrams - HF (high frequency) and LF (low frequency). The investigated environment differs considerably from site to site, both in terms of construction and of the environment GPR respond. In general, a considerable number of reflexes can be observed, both vertically and laterally. As part of the survey, 26 boreholes were driven passing through the solid layers to the incoherent subsoil. From the drilling works, individual interfaces are identified both within the asphalt concrete layers and their underlying layers, whether concrete or asphalt-coated aggregates. An incoherent layer of macadam or gravel was identified at the bottom of the well at all sites. The results of the passportization described the faults of the upper part of the roads in all localities within which road scales were also integrated. The processed radargrams could be divided into homogeneous sections, which indicate a section of road with similar parameters of the georadar signal responses. An integrated interpretation of the visual inspection with the marking of damaged road sections together with data from drilling works and radargrams can provide the client with a good view of the condition of selected roads around road dynamic scales and thus plan their eventual repairment.