INSTITUTE OF ROCK STRUCTURE AND MECHANICS
The Czech Academy of Sciences

DEPARTMENT OF SEISMOTECTONICS

THEMATIC RESEARCH FOCUS

- MONITORING AND ANALYSIS OF NATURAL AND INDUCED SEISMICITY
- IMPLEMENTATION OF NOVEL TECHNIQUES AND DEVICES FOR GEOPHYSICAL DATA ANALYSIS AND ACQUISITION WITH SPECIAL EMPHASIS ON SEISMICS
- NEAR-SURFACE AND CRUSTAL EXPLORATION VIA SEISMIC, GRAVIMETRIC AND RESISTIVITY DATA
- ACTIVE TECTONICS
- SEISMIC HAZARD

MAIN SCOPE OF RESEARCH

- **Seismic Monitoring**
  Carrying out permanent and temporary seismic measurements at regional and local seismic stations and local arrays. We are part of the Czech Regional Seismic Network, WEBNET in West Bohemia and REYKJANET (Iceland) together with IG CAS. We are also responsible for the north-eastern part of the MKnet in Slovakia.
- **ROTAPHONE Six-Component Seismograph**
  Prototyping novel sensors and devices for the acquisition of seismic data, including development of the ROTAPHONE to acquire both the translational and rotational components of ground motion induced by both natural and artificial events.
- **Analysis of Earthquakes, Moment Tensor Inversion**
  Analyzing earthquakes improves our understanding of the seismotectonic regime in regions.
- **Seismic Hazard Assessment**
  Developing new methods for the determination of seismic hazard for strategic buildings and infrastructure. The research includes investigation of attenuation as an important parameter for the hazard assessment and stability calculation of precariously balanced rocks.
- **Surface Wave Analysis**
  Joint analysis of surface waves according to advanced procedures (acquisition and inversion of multicomponent data).
- **Induced Seismicity**
  Investigation of characteristic differences between natural and induced seismicity. We are currently focusing on seismicity in geothermal areas.
- **Near-surface Geophysics**
  Seismic, resistivity and gravimetric data acquisition and analysis for near-surface studies (geotechnical applications, environmental monitoring, archaeological studies, geological mapping, seismic hazard evaluation, etc.).

FOCUS OF THE TEAM

The Department of Seismotectonics focuses on tectonic phenomena related to natural and induced seismic activity. It includes research of tectonic faults and fluid movement in the Earth's crust leading to earthquake generation, processes in earthquake foci and propagation of seismic waves in the heterogeneous rock massif.

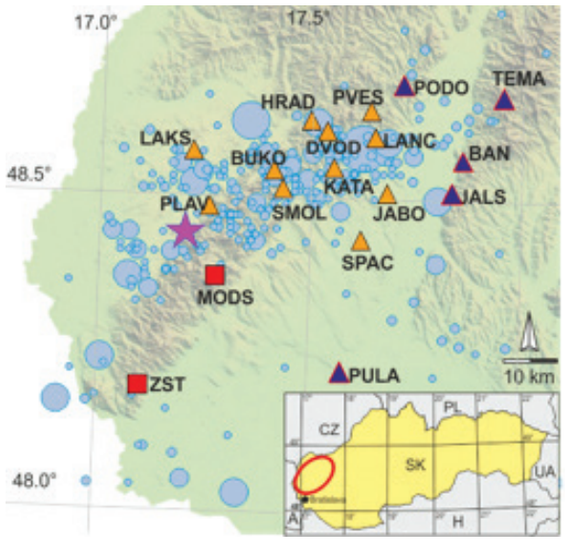
The main goal of these studies is to improve the seismotectonic models of seismically active regions. This comprises the development of new measurement methods, the continuous monitoring of seismicity and the improvement of processing algorithms and data interpretation. We especially develop methods for estimating seismic velocity structure, attenuation of seismic waves, precise locations, analysis of surface waves, moment tensor inversion, and, last but not least, seismic hazard assessment.

Our team is also active in the research of anthropogenic seismicity induced mainly by fluid injection in order to increase reservoir permeability during oil and gas production, create paths through rock in geothermal systems, and the gas storage, wastewater or CO_2 underground.

Moreover, the Department of Seismotectonics deals with problems of applied near-surface geophysics including environmental monitoring, archaeological studies, palaeoseismological surveys, geological mapping and geotechnical applications.

KEY RESEARCH EQUIPMENT

- Geode 24-channel seismograph (Geometrics)
- RUP2012/SeisComP seismic equipment for continuous monitoring
- 6 permanent seismic stations for the Czech Regional Seismic Network (CzechGeo/EPOS)
- 5 seismic stations for the MKnet Local Seismic Network, Slovakia
- 4 permanent small-aperture seismic arrays
- CG-5 gravity meter
- ARES geoelectric apparatus
- CMG-40T seismometer (Guralp Systems)
- STS-2 seismometer (Streckeisen)
- Rotaphones
- Solinst Groundwater Monitoring Instruments
- Keyence VHX-5000 digital microscope



The MKnet seismic network monitors seismic activity in the Malé Karpaty region. The blue circles symbolize earthquakes. The historical 1906 earthquake of magnitude 5.7 is shown by the big purple star. The stations JALS, BAN, PODO, PULA and TEMA are provided by IRSM CAS.

Installation of Rotaphone station near Litoměřice

Field work

ACHIEVEMENTS

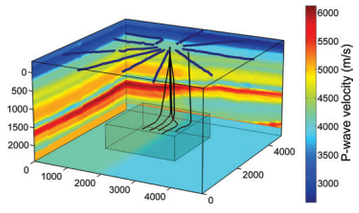
● MONITORING AND ANALYSIS OF NATURAL AND INDUCED SEISMICITY

Installation of a seismic station (TEMA, Slovakia)

Li L., Tan J., Schwarz B., Staněk F., Poiata N., Shi P., Diekmann L., Eisner L., Gajewski D., 2020. *Recent Advances and Challenges of Waveform-Based Seismic Location Methods at Multiple Scales.* Reviews of Geophysics, doi: 10.1029/2019RG000667.

Brokešová J., Málek J., 2020. *Comparative Measurements of Local Seismic Rotations by Three Independent Methods.* Sensors, doi: 10.3390/S20195679.

Staněk F., Eisner L., 2017. *Seismicity Induced by Hydraulic Fracturing in Shales: A Bedding Plane Slip Model.* Journal of Geophysical Research: Solid Earth, doi:10.1002/2017JB014213.



3D P-wave velocity model, wells and surface star-like monitoring array acquiring microseismic data during hydraulic fracturing in shale

Staněk F., Anikiev D., Valenta J., Eisner L., 2015. *Semblance for microseismic event detection.* Geophysical Journal International, doi: 10.1093/gji/ggv070.

Wcisło M., Stabile T.A., Telesca L., Eisner L., 2017. *Variations of attenuation and Vp/Vs ratio in the vicinity of wastewater injection: a case study of Costa Molina 2 well (High Agri Valley, Italy).* Geophysics, doi: 10.1190/geo2017-0123.1.

Fojtíková L., Vavryčuk V., 2018. *Tectonic stress regime in the 2003–2004 and 2012–2015 earthquake swarms in the Ubaye Valley, French Alps.* Pure and Applied Geophysics, doi: 10.1007/s00024-018-1792-2.

Brokešová J., Málek J., 2016. *Small aperture-array translational and rotational seismograms from distant sources – An example of the Jan Mayen Mw 6.8 of 30 August 2012 earthquake.* Physics of the Earth and Planetary Interiors, doi: 10.1016/j.pepi.2016.03.013.

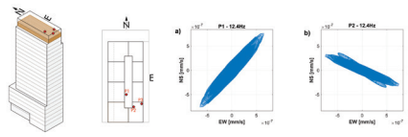
Vlček J., Eisner L., Stabile T.A., Telesca, L., 2017. *Temporal Relationship Between Injection Rates and Induced Seismicity.* Pure and Applied Geophysics, doi: 10.1007/s00024-017-1622-y.

● SURFACE WAVE ANALYSIS

Dal Moro G., 2015. *Joint Inversion of Rayleigh-Wave Dispersion and HVSR of Lunar Seismic Data from the Apollo 14 and 16 sites.* Icarus, doi: 10.1016/j.icarus.2015.03.017.

Dal Moro G., Moura R.M., Moustafa S., 2015. *Multi-component Joint Analysis of Surface Waves.* Journal of Applied Geophysics, doi: 10.1016/j.jappgeo.2015.05.014.

Dal Moro G., Weber T.M., Keller, L., 2018. *Gaussian-filtered Horizontal Motion (GHM) plots of non-synchronous ambient microtremors for the identification of flexural and torsional modes of a building.* Soil Dynamics and Earthquake Engineering, doi: 10.1016/j.soildyn.2018.05.018.



Characterization of the vibration modes of a building: identification of a torsional mode at 12.4 Hz for a three-storey building by means of the GHM (Dal Moro et al. 2018)

Dal Moro G., Al-Arifi N., Moustafa S.R., 2017. *Analysis of Rayleigh-Wave Particle Motion from Active Seismics.* Bulletin of the Seismological Society of America, doi: 10.1785/0120160063.

Lukešová R., Fojtíková L., Málek J., Kolínský P., 2019. *Seismic Waves Velocities Inferred From The Surface Waves Dispersion In The Malé Karpaty Mountains, Slovakia.* Acta Geodynamica et Geomaterialia, doi: 10.13168/AGG.2019.0038.

Zábranová E., Hanyk L., Matyska C., 2017. *Matrix eigenvalue method for free-oscillations modelling of spherical elastic bodies.* Geophysical Journal International, doi: 10.1093/gji/ggx353.

● SEISMIC HAZARD ASSESSMENT

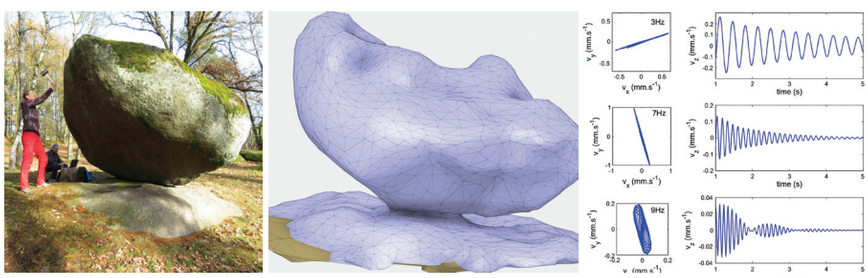
Málek J., Brokešová J., Vackář J., 2017. *Mid-European seismic attenuation anomaly.* Tectonophysics, doi: 10.1016/j.tecto.2017.06.003.

Wcisło M., Eisner L., Málek J., Fischer T., Vlček J., Kletetschka G., 2017. *Attenuation in West-Bohemia: evidence of high attenuation in the Nový Kostel focal zone and temporal change consistent with CO_2 degassing.* Bulletin of the Seismological Society of America, doi: 10.1785/0120170168.

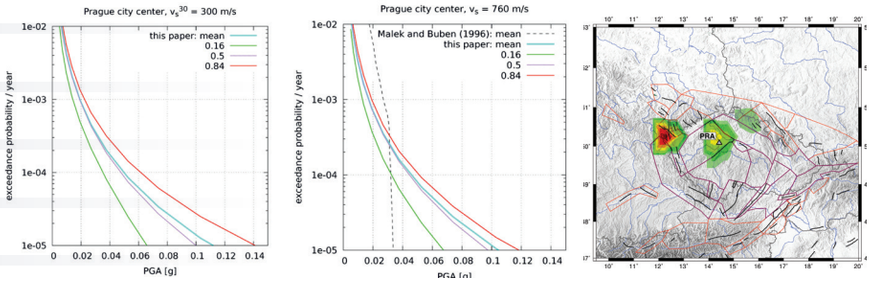
Entler S., Málek J., Brokešová J., 2017. *Moderní trendy seismického zabezpečení jaderných elektráren [Modern Trends in the Seismic Safety of Nuclear Power Plants].* Energetika, 67, 3, 179–184. ISSN 0375-8842.

Nováková L., 2016. *Paleoseismology: evidence of earth activity.* International Journal of Earth Sciences, doi: 10.1007/s00531-016-1331-2.

Zábranová E., Matyska C., Stemberk J., Málek J., 2019. *Eigenoscillations and Stability of Rocking Stones: The Case Study of "The Hus Pulpit" in The Central Bohemian Pluton.* Pure and Applied Geophysics, doi: 10.1007/s00024-019-02296-z.



Left: Seismic measurements of the Hus Pulpit balanced rock; middle: its 3-D digital model created from 163 images using the Agisoft PhotoScan software; right: Partical motion analysis of the three fundamental eigenoscillations of the Hus Pulpit.

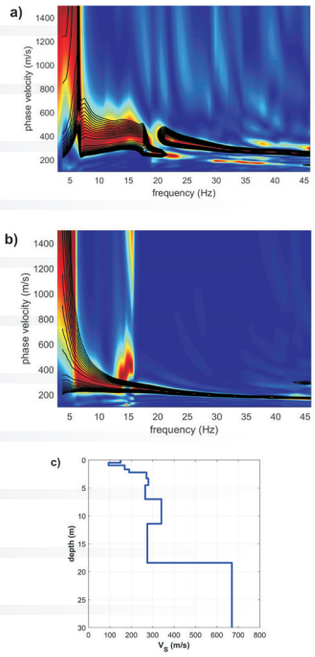


Seismic hazard curves for peak ground acceleration in Prague City
a) for sediment localities; b) for rock localities; c) disaggregation of seismic hazard

Málek J., Vackář J., 2019. *Site-specific probabilistic seismic hazard of Prague (Czech Republic).* Journal of Seismology, doi: 10.1007/s10950-019-09859-6.

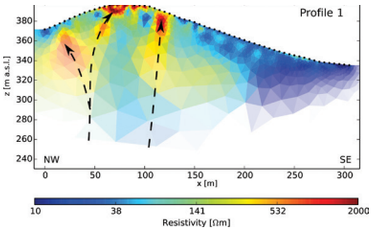
● NEAR-SURFACE GEOPHYSICS

Dal Moro G., Keller L., Al-Arifi N., Moustafa S.R., 2016. *Shear-wave velocity profiling according to three alternative approaches: a comparative case study.* Journal of Applied Geophysics, doi: 10.1016/j.jappgeo.2016.08.011.



Velocity model retrieved from measurement and analysis of phase velocity

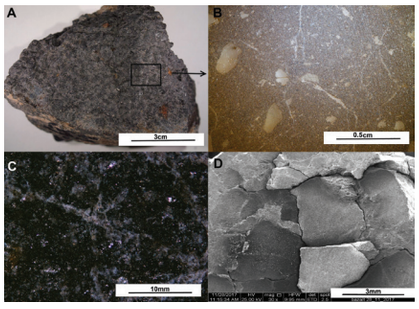
Petronis M., Valenta J., Rapprich V., Lindline J., Heizler M., van Wyk de Vries B., Shields S., Balek J., Fojtíková L., Tábořík P., 2018. *Emplacement history of the Miocene Zebín tuff cone (Czech Republic) revealed from ground geophysics, anisotropy of magnetic susceptibility, paleo-magnetic, and 40Ar/39Ar geochronology data.* Geochemistry, Geophysics, Geosystems, doi: 10.1029/2017GC007324.



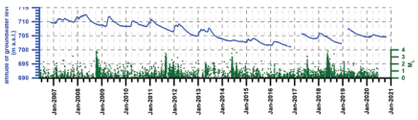
Two-dimensional inverted resistivity (electrical resistivity tomography) image of the Zebín Volcano along profile 1. The low-resistivity zones (up to approximately 100 Ωm, blue and bluish colours) represent clay-rich sediments, whereas the high resistivity areas (approximately 300 Ωm and more, red colours) represent coherent basic dikes. The possible magma feeder conduits/dikes are indicated by dashed arrows.

Málek J., Brokešová J., Novotný O., 2019. *Seismic structure beneath the Reykjanes Peninsula, southwest Iceland, inferred from array-derived Rayleigh wave dispersion.* Tectonophysics, doi: 10.1016/j.tecto.2018.12.020.

Nováková L., Schnabl P., Büchner J., 2018. *The characterization of sunburn basalts and their magnetic and petrographic properties.* Journal of Geosciences, doi: 10.3190/jgeosci.274.



The sunburn effect of basalt from macro to micro scale. a – Macro photograph of the sample, spots are clearly visible; b – Macro photograph of capillary cracks and analcite minerals; taken by digital microscope Keyence VHX-5000; c – Spots and "white sun" under the optical microscope with plane-polarized light; d – Cracks captured by SEM.



Variations in groundwater level in the S-4 well (a 97-m depth well located in Lázně Kynžvart, Western Bohemia) and seismic activity in the years 2006–2020. M_L stands for local magnitude, derived from the WEBNET Catalogues of Local Earthquakes.

MAIN COLLABORATING PARTNERS

- Geophysical Institute of the CAS (CZ)
- Geological Institute of the CAS (CZ)
- Czech Geological Survey (CZ)
- Charles University in Prague, Faculty of Science, Faculty of Mathematics and Physics (CZ)
- Czech Technical University in Prague, Faculty of Electrical Engineering (CZ)
- Earth Science Institute of the Slovak Academy of Sciences (ESI), Slovakia
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- New Mexico Highland University, USA
- Institute of Geology and Geophysics of the Chinese Academy of Sciences, China
- Geological Survey of Ethiopia
- ETH, Zurich, Switzerland
- University of Trieste, Italy
- Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA) Rome, Italy
- King Saud University (Riyadh, Saudi Arabia)
- TU Bergakademie Freiberg, Germany
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- University of Memphis, USA
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