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
- NEAR-SURFACE AND CRUSTAL EXPLORATION VIA SEISMIC, GRAVIMETRIC AND RESISTIVITY DATA
- IMPLEMENTATION OF NOVEL TECHNIQUES AND DEVICES FOR GEOPHYSICAL DATA ANALYSIS
- ACTIVE TECTONICS
- SEISMIC HAZARD
- GEOTHERMAL ENERGY

MAIN SCOPE OF RESEARCH

- **Seismic Monitoring**
  Carrying out permanent and temporary seismic measurements at regional and local seismic stations in the Czech Republic, Slovakia, Romania, Iceland, and Ethiopia. We are part of the Czech Regional Seismic Network. The research includes the development and testing of new seismic instruments.
- **Analysis of Earthquakes, Moment Tensor Inversion**
  Analyzing earthquakes improves our understanding of the seismotectonic regime in regions.
- **Seismic Hazard Assessment**
  Evaluating seismic hazard for existing as well as planned nuclear facilities (power plants, nuclear waste storage, planned small modular reactors). Developing novel methods for Bayesian uncertainty evaluation in low seismicity areas for probabilistic seismic hazard assessment. The research includes the investigation of attenuation as an important parameter for the hazard assessment and stability calculation of precariously balanced rocks.
- **Surface Wave Analysis**
  Surface wave analysis for near-surface applications using advanced multicomponent and multiobjective approaches with active and ambient seismic data.
- **Geothermal Energy**
  Problems of geothermal energy exploration mainly in theoretical studies of heat propagation in rock environments. Geothermal energy extraction and storage through boreholes has garnered significant attention, as it can play a crucial role in the decarbonization of district heating networks.
- **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 site characterization, etc.).

FOCUS OF THE TEAM

The Department of Seismotectonics focuses on tectonic phenomena related to seismic activity. It includes research on 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 data acquisition 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 seismic hazard assessment.

The Department of Seismotectonic deals with problems of geothermal energy, mainly the propagation of heat in different environments.

Moreover, our team is also active in the research of applied near-surface geophysics, including geological mapping and geotechnical applications.

Equipment for the acquisition of surface wave data for site characterisation (Geode).

KEY RESEARCH EQUIPMENT

- Geode 24-channel Seismograph (Geometrics) + vertical, horizontal and 3C geophones
- Seismic equipment for continuous monitoring – SeisLogger310 (developed in-house) / SeisComP
- 6 Permanent Seismic Stations for Czech Regional Seismic Network
- 5 Seismic Stations for the MKnet local seismic network, Slovakia
- 3 Seismic Stations for the "East Bohemia" local seismic network
- CG-5 Gravity Meter
- ARES Geoelectric Apparatus
- CMG-40T Seismometer (Guralp Systems)
- STS-2 Seismometer (Streckeisen)
- GEO-S120 Seismometer (GEObit)
- Rotaphone – D (disc) – developed in-house
- Rotaphone – B (burial) – developed in-house
- Solinst Levelogger for groundwater monitoring
- BRS-32 Bump Recorder for monitoring quarry blasts
- Smart Solo IGU-16HR 3C 5Hz all-in-one stations

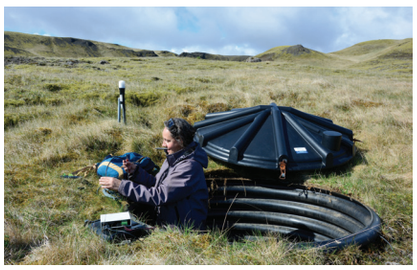
Research In Vrancea

Active participation in the AdriaArray initiative, contributing to large-scale seismic monitoring across Europe with a focus on the Vrancea area in Romania, one of the most dangerous areas in the sense of seismic hazard.

Research In Iceland

Measuring and analysing seismic data from the Reykjanes Peninsula, an area with significant seismic and volcanic activity, focusing on the relationship between the attenuation of seismic waves and the structure beneath the area since 2013.

Adria Array installation of the Rotaphone.



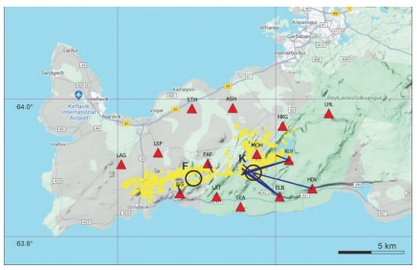
Field work –maintenance of a seismic station – the Rotaphone close to Katla volcano, Iceland.

Research In Ethiopia

Monitoring the region's primary sources of seismicity – the rift bottom, associated with magmatic intrusions, and the western margin of the rift. Investigating the tectonically and magmatically induced seismicity around the municipality of Arba Minch, Ethiopia, with respect to seismic hazard assessment and geothermal energy utilisation.

Research In Slovakia

Measuring seismic data and refining the seismotectonic model in the Western Carpathians.



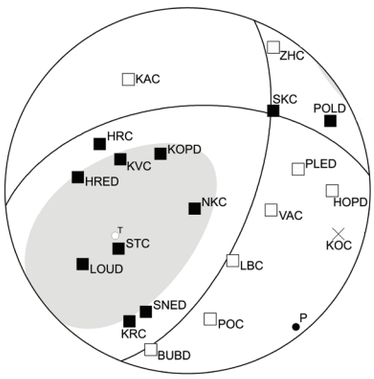
Selected earthquakes in the Reykjanes Peninsula during December 2019 – October 2020 (yellow dots) and REYKJANET stations (red triangles). Two important volcanic sites are shown with black circles, F – Fagradasfjall and K – Krýsuvík at the central part of REYKJANET; anomalous rays with high attenuation (small amplitudes) – dark--blue colour.

Building seismic stations in the Arba Minch area.

ACHIEVEMENTS

● ANALYSIS OF NATURAL AND INDUCED SEISMICITY

Křížová D., Málek J. (2021): Focal Mechanisms of West Bohemia, Central Europe, Earthquakes – End of May 2014: Evidence of Volume Changes. Seismological Research Letters 92 (6), 3398–3415.

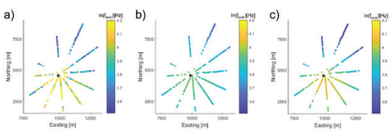


Focal mechanism plot for the strongest earthquake (31 May 2014, 10:37:21.11) with signs of first motion for available WEBNET data. Black squares mean "up" and white "down"; T and P axes are depicted by circles.

Li L., Tan J., Schwarz B., Stanek 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 58 (1), 03691316.

Stabile T. A., Vlček J., Wcisło M., Serlenga V. (2021): Analysis of the 2016–2018 fluid-injection induced seismicity in the High Agri Valley (Southern Italy) from improved detections using template matching. Scientific Reports 11, 20630.

Wcisło M., Staněk F., Gallovič F., Wu S., Pšenčík I. (2023): Induced Microseismic Event with Strong Rupture Directivity and Superimposed Attenuation Effects. Seismological Research Letters 94 (3), 1455–1466.



Different scenarios for the attenuation and directivity of rupture propagation.

Malytskyy D.V., Fojtíková L., Málek J., Gnyp A.R., Astashkina O.A., Nikulins V.G., Pak R.M. (2024): Seismic moment tensor and focal mechanism of the October 9, 2023 earthquake in Eastern Slovakia. Geodynamics 36 (1), 5–11.

● GEOTHERMAL ENERGY

Fischer T., Vlček J., Dědeček P., Řihošek J., Zimmermann G., Holeček J., Mazanec M., Rukavičková L., Janků L., Káldy E. (2023): Hydraulic injection tests in the pilot EGS borehole PVGT-LT1 in Litoměřice, Czechia. Geothermics 115, 102805.

Matyska C., Zábranová E. (2023): Heat extraction calculations for deep coaxial borehole heat exchangers: matrix analytical approach. Geophysical Journal International 235 (3), 2323–2338.

Matyska C., Zábranová E. (2024): Seasonal energy extraction and storage by deep coaxial borehole heat exchangers in a layered ground. Renewable Energy, 237 (A), 121530.

● NOVEL TECHNIQUES

Brokešová J., Málek J. (2020): Comparative Measurements of Local Seismic Rotations by Three Independent Methods. Sensors 20 (19), 5679.

Pšenčík I., Wcisło M., Daley P.F. (2021): SH plane-wave reflection/transmission coefficients in isotropic, attenuating media. Journal of Seismology 26 (1), 15–34.

Brokešová J., Málek J. (2024): Rotaphone-D, A New Model of Six-Degree-of-Freedom Seismic Sensor: Description and Performance. Seismological Research Letters 96 (2A), 968–979.

Lukešová R., Málek J. (2024): Seismic Beacon – A New Instrument for Detection of Changes in Rock Massif. Sensors 24 (1), 234

Prototype of a seismic beacon installed in an old military bunker

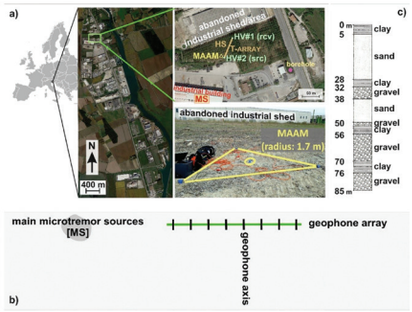
● SURFACE WAVES ANALYSIS

Dal Moro G. (2020): The magnifying effect of a thin shallow stiff layer on Love waves as revealed by multi-component analysis of surface waves. Scientific Reports 10, 9071.

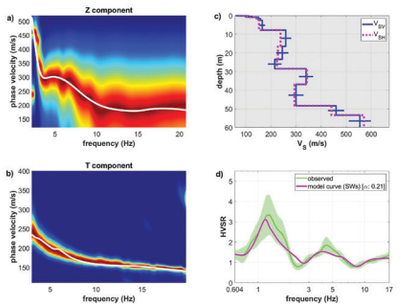
Mazanec M., Valenta J. (2023): Surface Waves as a Cost-Effective tool for Enhancing the Interpretation of Shallow Refraction Seismic Data, Acta Geodynamica et Geomaterialia 20 (3) (211), 121–138.

Dal Moro G., Mazanec M. (2024): Determination of the VS profile at a "noisy" industrial site via active and passive data: The critical role of Love waves and the opportunities of multicomponent group velocity analysis. Geophysics 89 (3), B209–B227.

Dal Moro, G. (2020): Efficient Joint Analysis of Surface Waves and Introduction to Vibration Analysis: Beyond the Clichés. Springer, pp. 1–266.



Location and survey design: a) location of the investigated site, map of the recorded seismic data and photo with the highlighted triangular array used for the MAAM; b) scheme of the linear array for the T-component array; c) stratigraphy of the nearest available borehole, from Dal Moro and Mazanec (2024).

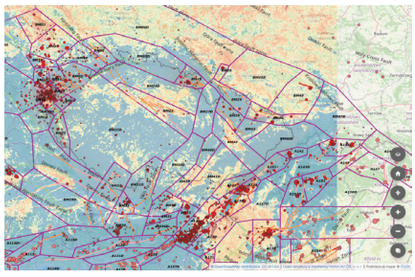


Joint analysis of Rayleigh- and Love-wave dispersion together with the HVSR: a) phase-velocity effective dispersion of the Z component of Rayleigh waves; b) phase-velocity effective dispersion of the T component (Love waves); c) HVSR (field and modelled curves); d) obtained shear-wave velocity profile (VSV and VSH values) (also reported the standard deviations obtained considering the final Pareto front models) from Dal Moro and Mazanec (2024)

● SEISMIC HAZARD ASSESMENT

Mazanec M., Valenta J., Málek J. (2024): Does VS30 reflect seismic amplification? Observations from the West Bohemia Seismic Network. Natural Hazards 120, 12818–12202.

Lukešová R., Fojtíková L., Vackář J., Málek J. (2025): Increased seismicity at the beginning of the twentieth century in the intraplate region of Czechia and neighboring areas in Central Europe. Environmental Earth Science 84, 102.



Preview of the website: www.seismickamapa.cz

● EXPLORATION IN THE CZECH REPUBLIC AND REMOTE AREAS

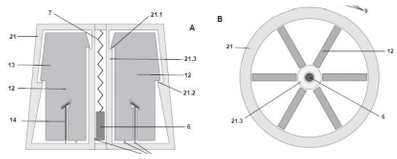
Málek J., Brokešová J., Novotný O. (2023): New Velocity Structure of the Nový Kostel Earthquake-Swarm Region, West Bohemia, Determined by the Isometric Inversion. Pure and Applied Geophysics 180, 2111–2134.

Malytskyy D., Křížová D., Lognonné P., Kawamura T., Perrin C., Plasman M., Xu Z., Maguire R. (2024): High- and low-frequency waveform analysis the Marsquake of Sol 1222: Focal mechanism, centroid moment tensor inversion, and source time function. Earth and Space Science 11, e2023EA003272.

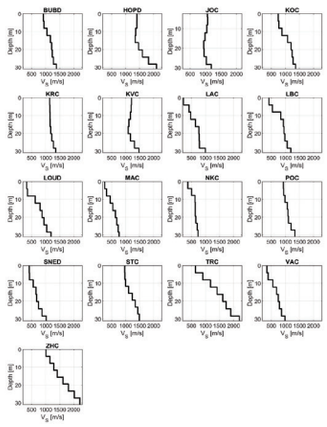
Valenta J., Verner K., Martínek K., Hroch T., Buriánek D., Megerssa L.A., Boháč J., Kassa M., Legesse F., Yakob M., Kebede B., Málek J. (2021): Ground fissures within the Main Ethiopian Rift: Tectonic, lithological and piping controls, Earth Surface Processes and Landforms 46 (15), 3158-3174.

● PATENTS

Málek, J. (2023): Patent No. CZ 309648 B6, Harmonic Seismic Wave Generator and Assembly for Seismic Prospecting



Sketch of the Rotagraph.

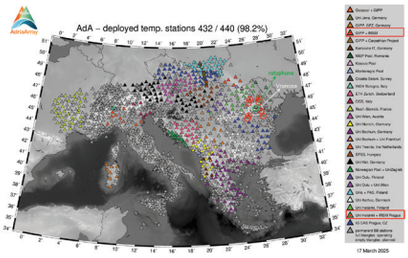


Shear-wave velocity profiles of 16 WEBNET sites obtained using MASW (from Mazanec et al. 2024).

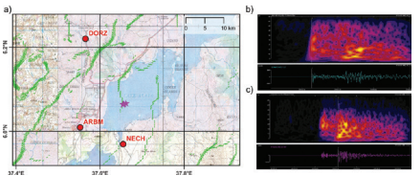
Field work – acquisition of surface wave data for site characterisation.

Seismic station in Ethiopia

Field work – building a seismic station in Iceland.



Deployment of seismic stations for the European AdriaArray experiment. As part of this project, IRSM's Department of Seismotectonics focuses on the seismically active Vrancea region in Romania.



Recent seismic activity (10 November, 2024) monitored in the Arba Minch area. a) locations of three events (magenta asterisks) and position of the Linsser indications for the depth of 1 km (green symbols); b) seismogram and spectrogram for the Z component of the 17:24 event; c) the same for the horizontal (E component) of this event

MAIN COLLABORATING PARTNERS

- Institute of Geophysics of the CAS (Prague, CZ)
- Institute of Geology of the CAS (Prague, CZ)
- Czech Geological Survey (Prague, CZ)
- Charles University in Prague, Faculty of Science, Faculty of Mathematics and Physics (Prague, CZ)
- Czech Technical University in Prague, Faculty of Electrical Engineering (Prague, CZ)
- Earth Science Institute of the Slovak Academy of Sciences (ESI) (Slovakia)
- NIEP – National Institute for Earth Physics (Romania)
- Geological Survey of Ethiopia
- Icelandic Geological Survey ÍSOR, (Iceland)

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