



**Institute of Rock Structure and Mechanics
of the Czech Academy of Sciences**



ANNUAL REPORT 2021

Translation

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For informative purposes only. The legally binding text is the one in Czech.

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I. Information on the composition of the statutory bodies of the Institute of Rock Structure and Mechanics of the Czech Academy of Sciences (IRSM) and the activities thereof

Composition of the Institute's statutory bodies

Managing Director: RNDr. Josef Stemberk, CSc.

Board of the Institute:

Chairperson: Ing. Martin Černý, PhD.

Vice-chairperson: Mgr. Martina Havelcová, PhD.

Internal members: Ing. Olga Bičáková, PhD.,
RNDr. Jiří Málek, PhD.,
RNDr. Josef Stemberk, CSc.
Ing. Tomáš Suchý, PhD.
RNDr. Petra Štěpančíková, PhD.

External members: Prof. RNDr. Pavel Coufal, PhD.
(Charles University, Faculty of Natural Sciences),
Prof. RNDr. Tomáš Fischer, PhD.
(Charles University, Faculty of Natural Sciences),
Ing. Pavel Kriegsmann, (KM, s.r.o.),
RNDr. Bohuslav Růžek, CSc.
(Academy of Sciences, Geophysical Institute)

Secretary to the Board: Doc. RNDr. Pavel Straka, CSc., DrSc.

Supervisory Board:

Chairperson: RNDr. Pavel Krejčí, CSc.
(Academy of Sciences, Mathematical Institute)

Vice-chairperson: Mgr. Lucia Fojtíková, Ph.D.
(Academy of Sciences, IRSM)

Members: Ing. Radek Sedláček, PhD., (Czech Technical University,
Faculty of Mechanical Engineering),

Doc. RNDr. Bohdan Kříbek, DrSc.
(Czech Geological Survey)

Prof. RNDr. Jakub Langhammer, PhD.
(Charles University, Faculty of Natural Sciences)

Secretary to the Board: RNDr. Filip Hartvich, PhD.

Activities of the Institute's statutory bodies

Managing Director:

- The managing director issued a total of 8 organisational communications and 4 instructions during 2021. Meetings were held on a monthly basis between the Institute's management and heads of department.
- Contracts were concluded for 3 new Czech Grant Agency (GA CR) projects and 1 Technology Agency of the Czech Republic (TA CR) project
- The publication activities of the Institute's researchers were assessed in the form of a competition and the results subsequently published.
- A new directive on the method for managing the results of the scientific and research activities of the IRSM was submitted and subsequently approved by the Board of the Institute.
- A new salary regulations table was submitted and approved by the Board of the Institute.
- A proposal to increase the contribution to employees from the cultural and social needs fund to CZK 12,000 per year was submitted and approved by the Board of the Institute.
- Based on a request submitted by the heads of the Institute's scientific departments, attestation proceedings were initiated concerning a number of IRSM researchers.
- Two construction projects were realised during the year: the reconstruction of sanitary facilities on the 4th floor of building D and the completion of the reconstruction of the centrifuge building for the installation of an electron microscope. Moreover, co-financing was used for the fitting of the electron microscope with sample preparation equipment, and a new economic information system was acquired and put into operation on 1 January 2022.

Board of the Institute:

The Board of the Institute held four regularly-scheduled meetings during 2021: 15 April, 11 October, 23 November and 14 December.

- 15 April. The following issues were discussed: the activities of the IRSM during the 1st quarter of 2021, information on the new economic information system, the fulfilment of the budget in 2020, the IRSM draft budget for 2021, the preparation of the IRSM Annual Report for 2020 and the documentation for applications for the support of salaries for postdoctoral students.
- 11 October. The following issues were discussed: the Report on the Results of the Evaluation of the Institute by International Commissions for the Period 2015–2019, including the reservations contained in the evaluation, the draft Directive on the Management of the Results of the Scientific and Research Activities of the IRSM and the further development of salaries.
- 23 November. The following issues were discussed: a draft of the new IRSM salary regulations including comments to the draft, the acceptance of the decision of the Academic Council of the Academy of Sciences (AS CR) regarding the IRSM's obligation to pay the company that repaired the depository of The Masaryk Institute and Archive of

the AS CR Library (AS CR) and the preparation of, and procedure to be applied for the election of members to the new Board of the Institute.

- 14 December. The Board approved new tables of tariff salary ranges and bonuses for the managers of departments and discussed the Managing Director's report on the activities and management of the Institute in 2021, the international evaluation of the Institute for the period 2015–2019 and the results of the IRSM publication competition. The Board noted that the selection procedure for the position of Managing Director of the Institute will take place next year. The deadline for applications for the position was set at 31 January 2022. With concern to this issue, it will be necessary to adjust the requirements regarding the professional qualifications of the Managing Director due to the composition of scientific disciplines represented at the IRSM.

Supervisory Board:

In accordance with the Rules of Procedure, the Supervisory Board met twice in 2021, and discussed 1 issue via letter. The Board was provided with the financial results of the Institute, its 2020 Annual Report and the budget for 2021.

The first meeting of the Board, held on 4 June 2021, included the verification and approval of the minutes of the February 2020 meeting, a discussion on the disbursement of the IRSM budget in 2020 and the outlook for 2021, and a discussion on, and the noting of, the financial and auditor's reports for 2020. Further, the Board discussed and approved the Report on the Activities of the IRSM Supervisory Board for 2020 and the IRSM 2020 Annual Report. The activities and results of the IRSM were discussed and the Board was informed of organisational changes and scientific and management issues. A draft assessment of the Managing Director of the IRSM was discussed and subsequently approved.

At its second meeting, which took place on 17 December 2021, the Board verified and approved the minutes of the January 2021 meeting and postal vote no. 2/2021. The Board also discussed the disbursement of the budget in 2021 and the outlook for 2022, discussed the activities and results presented by the Managing Director in 2020 and approved prior written consent to the intention of the IRSM to use a military building on a free-of-charge basis. In conclusion, the Board approved a resolution on the recognition of the contribution made by RNDr. Josef Stemberk, CSc. to the development of the Institute.

During 2021, the Board discussed and approved one draft resolution by letter, namely the appointment of ACONTIP, s.r.o. as the financial auditors of the IRSM for 2021 (adopted on 14 October 2021).

II. Information on changes to the Institute's charter

No changes were made to the Institute's charter during the year.

III. Evaluation of the Institute's main activities

1. Results of the Institute's scientific activities

The scientific activities of the Institute were performed in the context of the Long-term Research Organisation Conceptual Development Project, no. RVO 67985891 and

concerned both research in selected geoscientific fields and the socially desirable research of materials.

- Geoscientific research:

The study of the properties of rocks employing instrumental methods and the research of rocks focusing on the conditions for the emergence of natural and induced geodynamic processes and activities in the upper layer of the earth's crust, namely:

- processes that threaten the stability of the earth's surface and the minimisation of their adverse impacts;
- the monitoring and study of the propagation of seismic waves in various rock environments;
- the monitoring and analysis of slope and tectonic movements;
- the study of the paleo-stress conditions in the Czech massif;
- the study of neo tectonic phenomena in the Himalayas and Turkey.

- Materials research:

The study of raw materials and organic and inorganic materials focusing on their origin and properties and with regard to their use in the medical, glassmaking, construction and environmental technology sectors, namely:

- the preparation and research of the properties of collagen materials for use in the field of vascular surgery, the modelling of smelting processes, the development of new smelting facilities and the vitrification of radioactive waste;
- the preparation of special glass materials that are permeable to infrared radiation and the characterisation thereof;
- the development of hybrid composites with reinforcement for lightweight roofing purposes;
- the preparation of new geopolymer composites aimed at reducing the ecological burden;
- the development of technologies for the heat treatment of sludges, biomass and plastic waste.

The Institute achieved a number of significant research results during the year via international cooperation, especially with foreign research institutions, cooperation with domestic research facilities, universities and other institutes of the Academy of Sciences of the Czech Republic and cooperation with industrial organisations (Astron, s.r.o., Devro, a.s., UJP Praha, a.s., DIAMO, etc.). Three outcomes are described below as examples of successful international cooperation:

- 1) The detection of active faults in intramountain basins using electrical resistivity tomography in the Kashmir basin, north-western Himalayas.

Summary:

Electrical resistivity tomography was used to detect active faults in the intramountain Kashmir basin in the NW Himalayas. Two secondary active subsidence faults were detected at two locations in the NW part of the Kashmir basin, which were designated as the NW Kashmir and Delina faults. These faults apparently comprise secondary shallow faults of a primary fault system, which occurs at depth and does not reach the surface. This was further evidenced by the rapid uplift of the Karewa sediments in the vicinity of the survey sites. From the methodological point of view, electrical resistivity

tomography proved to be a very effective method for the detection of active faults in intramountain basins with a high degree of information provision potential.

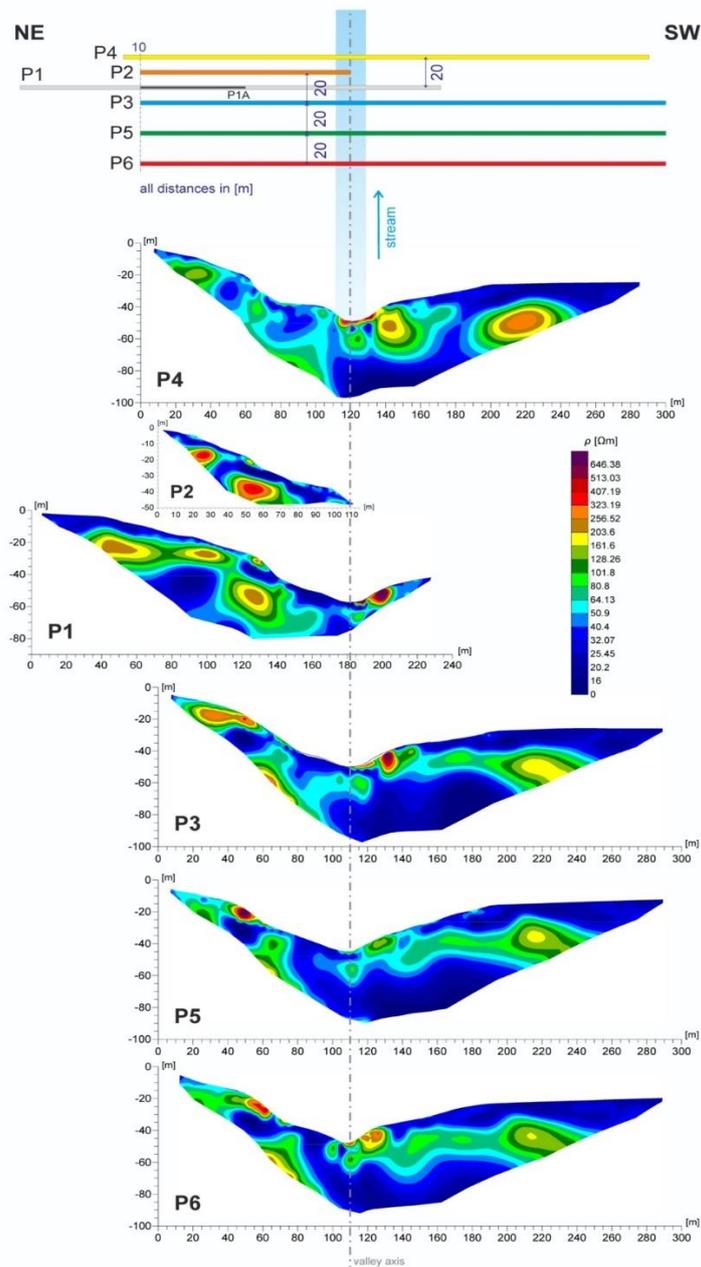
The results were achieved in cooperation with the Department of Geology and Mining, Srinagar, Jammu and Kashmir, India.

Publication:

Sana Hamid, Tábořík Petr, Valenta Jan, Bhat Fayaz A., Flašar Jan, Štěpančíková Petra, Khwaja Nisar A.: Detecting active faults in intramountain basins using electrical resistivity tomography: A focus on Kashmir Basin, NW Himalaya. *Journal of Applied Geophysics* 192, 2021, 104395. DOI:10.1016/j.jappgeo.2021.104395.

Illustration:

The results and interpretation of a geophysical survey employing the electrical resistivity tomography (ERT) method at the Chaksari site, NW area of the Kashmir basin. The Figure illustrates ERT profiles P1–P6. The generalised valley axis is indicated by the dashed line.



2) Interpretation of the influence of glaciation and climate changes on the formation and stability of a catastrophic rock slide, Cordillera Blanca, Peru

Summary:

The stability of a rock slope above a glacial lake was reliably described thanks to the application of a range of classical and modern methods, e.g. satellite measurements of the surface deformation, which allowed for the assessment of the degree of the risk of a catastrophic rock slide in the various stages of the glacial development of the valley and at the present time. The results revealed a significant change in terms of the degree of risk due to the gradual warming and retreat of the feed glacier, to which the observed slope reacts only after a significant time delay caused by the working of various internal processes within the rock mass.

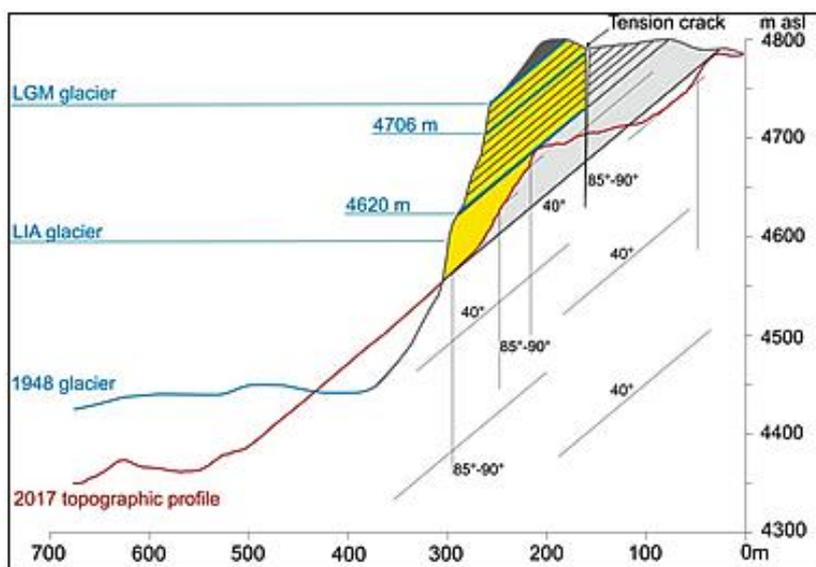
The results were achieved in cooperation with Autoridad Nacional de Agua, Área de Evaluación de Glaciares y Lagunas, Peru; Gamma Remote Sensing, Switzerland; Department of Geography, University of Zurich, Switzerland; ZHAW School of Life Sciences and Facility Management, Switzerland.

Publication:

Klimeš Jan, Novotný Jan, Rapre Alejo Cochacin, Balek Jan, Zahradníček Pavel, Strozzi Tazio., Sana Hamid, Frey Holger, René Miloš, Štěpánek Petr, Meitner Jan, Junghardt Johan: Paraglacial rock slope stability under changing environmental conditions, Safuna Lakes, Cordillera Blanca Peru. *Frontiers of Earth Science* 2021, 1–22.

DOI: 10.3389/feart.2021.607277

Illustration:



The engineering-geological model used for the assessment of the stability of the slope prior to the occurrence of a rock avalanche in 2002 that progressed across the main escarpment. The yellow area represents the proposed initial rock block failure that followed the collapse of the slope. The grey and hatched areas show the predicted masses of the 2002 rock avalanche, defined by the post-failure morphology and the structural conditions. The recent topographic profile is shown in red. The blue lines

indicate the proposed slip planes used for the slope stability calculations under various glaciation scenarios.

- 3) Model for batch-to-glass conversion: coupling heat transfer with conversion kinetics.

Summary:

A batch-to-glass conversion model was created of the melting furnace to the glass packaging process for the purpose of the study of advanced glass production technologies. The model includes the relationships between the temperature history of the strain particles, the strain properties and the melting rate, coupled with heat transfer and strain conversion kinetics. While the heat transfer in the batch is calculated by means of a one-dimensional convective-conductive heat balance model, the conversion kinetics are described using models based on sand particle dissolution data (Avrami and Šesták–Berggren models and stretched exponential kinetic equations).

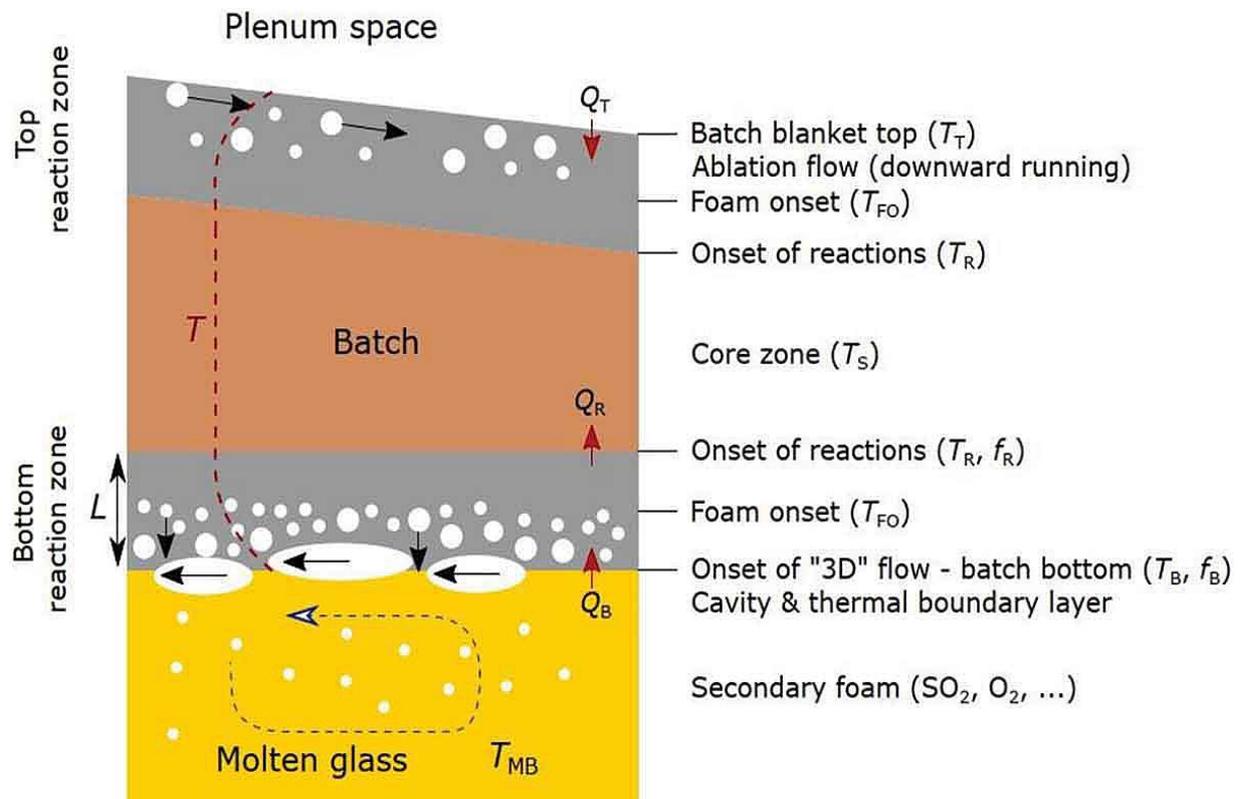
The results were achieved in cooperation with the Pacific Northwest National Laboratory (USA) and the U.S. Department of Energy (USA).

Publication:

Ferkl Pavel, Hrma Pavel, Kloužek Jaroslav, Vernerová Miroslava, Kruger Albert, Pokorný Richard: Model for batch-to-glass conversion: coupling the heat transfer with conversion kinetics. Journal of Asian Ceramic Societies 9, 2021, 652–664.

DOI: [org/10.1080/21870764.2021.1907914](https://doi.org/10.1080/21870764.2021.1907914)

Illustration:



Schematic diagram of a floating batch structure in a natural gas-fired furnace. The upper surface is inclined and the batch trunk is thawed on a continuous basis. The red

dashed line illustrates the temperature profile T ; Q is the heat flux and L is the thickness of the reaction zone. The subscripts S, R, B, T, FO and MB correspond to the batch, reaction zone, bottom edge of the batch, upper layer of the batch, foam regions and molten glass.

2. Activities and selected results of the Institute's scientific departments

The Institute conducted its scientific activities during the year via all six of its research departments, four of which focused on geoscientific and two on materials disciplines:

Geoscientific research was conducted by the departments of Engineering Geology, Neotectonics and Thermochronology, Seismotectonics and Geochemistry.

Materials research was performed by the Composite and Carbon Materials and the Structure and Properties of Materials departments.

The institute's scientific departments benefit from the sharing of research facilities with various universities. The department of Geochemistry's sorption and porosimetry analysis laboratory is shared with the Faculty of Science of the Charles University. Similarly, the department of Structure and Properties of Materials' inorganic materials laboratory is shared with the University of Chemical Technology, Prague.

In 2021, the Institute's scientific departments were involved in the following Strategy AV21 research programmes: Water for Life, Systems for Nuclear Energy, QUALITAS - Quality Life in Health and Disease, New Materials Based on Metals, Ceramics and Composites, Efficient Energy Conversion and Storage, and the City as a Laboratory of Change: buildings, cultural heritage and environments for a safe and rewarding life.

The staff of the Institute's scientific departments continued to be involved in teaching at various universities in 2021.

The Department of Engineering Geology focuses on the analysis and interpretation of dangerous geodynamic phenomena associated with exogenous processes, i.e. slope deformations and weathering. Particular attention was devoted during the year to the development of reliable and accurate monitoring methods for the monitoring of slope phenomena, especially landslides, and the prediction of their future occurrence and development.

The department was involved in international research on slope deformations and tectonic structures via the use of the following monitoring networks:

- Name: TecNet

Monitored issue: slow movements along tectonic faults.

Operator: IRSM (RI/OP VVV programme).

Content: tracking of seismic tectonic movements along faults.

- Name: Geonas

Monitored issue: GNSS fixed point movements.

Operator: IRSM (RI/OP VVV programme)

Content: background materials for the monitoring of tectonic movements.

- Name: Landslides, rockfalls and debris flows described in the media since 2011

Monitored issue: the emergence and reactivation of slope deformations in the Czech Republic

Operator: IRSM (NASA programme)

Content: to determine the location and time of the occurrence of landslides and the damage they cause.

- Name: SlopeNet.

Monitored issue: slope movements and landslides and rockfalls.

Operator: IRSM (RENS programme)

Content: the monitoring of slope movements and rockfalls.

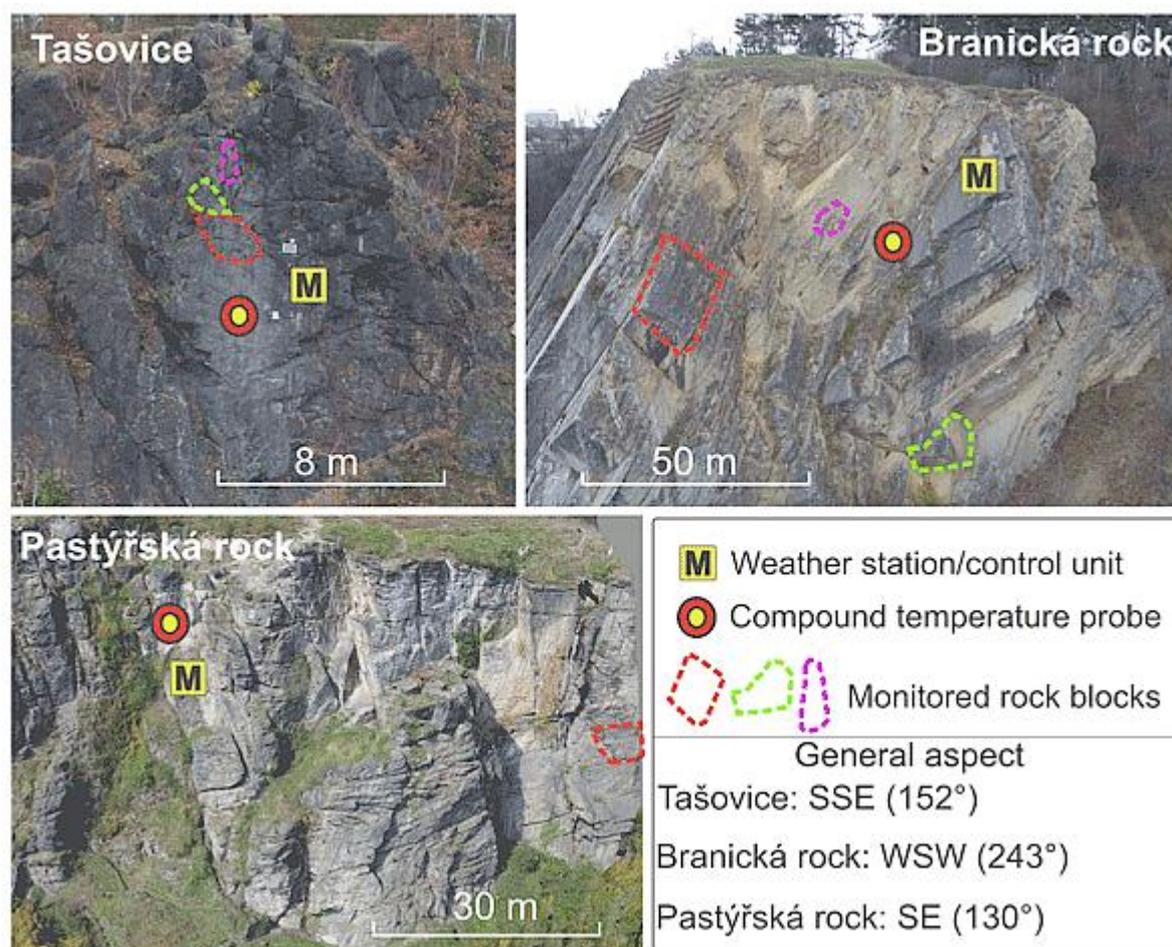
Main output:

Thermal regime of a rock slope and the monitoring of its stability using crack meters: initial results from three locations in the Czech Republic.

Summary: The project involves the creation of a universal, modular and, at the same time, affordable rock slope monitoring system, which allows for the *in-situ* observation of climate variables, the temperature in an up to three-metre surface layer and the dynamics of selected discontinuities over time. The initial observations have already allowed for the identification of differences and even significant differences between the three locations in the Czech Republic. The extensive statistical analysis of the data is planned based on longer-term monitoring periods. The data will be further used for numerical thermomechanical modelling purposes and the analysis of trends in the development of crack meters.

Publication: Racek O., Blahůt J., Hartvich F.: Observation of the rock slope thermal regime, coupled with crack meter stability monitoring: initial results from three different sites in Czechia (central Europe). *Geoscientific Instrumentation, Methods and Data Systems* 10, 2021, 203–218.

DOI: [org/10.5194/gi-10-203-2021](https://doi.org/10.5194/gi-10-203-2021)

Illustration:

The three monitored rock slope locations: Tašovice (Karlovy Vary), Branická rock (Prague) and Pastýřská rock (Děčín). The monitored blocks are marked with coloured dashed lines. The positions of the weather stations and the temperature probes in the boreholes are marked as M and red-yellow circles respectively.

Further outputs:

- Loche M., Scaringi G., Blahůt J., Melis M.T., Funedda A., Da Pelo S., Erbi I., Deiana G., Meloni MA, Cocco F.: An infrared thermography approach to evaluate the strength of a rock cliff. *Remote Sensing* 13(7), 2021, 1265, 1–13.

DOI: [org/10.3390/rs13071265](https://doi.org/10.3390/rs13071265)

- Šebela S., Stemberk Josef, Briestenský M.: Micro-displacement monitoring in caves at the Southern Alps–Dinarides–Southwestern Pannonian Basin junction. *Bulletin of Engineering Geology and the Environment* 80, 2021, 7591–7611.

DOI: [10.1007/s10064-021-02382-4](https://doi.org/10.1007/s10064-021-02382-4)

- Klimeš J., Novotný J., Rapre A. C., Balek J., Zahradníček, P., Strozzi T., Sana H., Frey H., René M., Štěpánek P., Meitner J., Junghardt J., 2021. Paraglacial Rock Slope Stability Under Changing Environmental Conditions, Safuna Lakes, Cordillera Blanca Peru. *Frontiers in Earth Science* 9, 607277, 1–24.

DOI: [10.3389/feart.2021.607277](https://doi.org/10.3389/feart.2021.607277)

- Smolíková J., Hrbáček F., Blahůt J., Klimeš J., Vilímek V., Loaiza Usuga J.C.:

Analysis of the rainfall pattern triggering the Lemešná debris flow, Javorníky Range, the Czech Republic. *Natural Hazards* 106, 2021, 2353–2379.

DOI: [org/10.1007/s11069-021-04546-7](https://doi.org/10.1007/s11069-021-04546-7)

- Blahůt J., Jaboyedoff M., Thiebbes B: Novel Approaches in Landslide Monitoring and Data Analysis. *Applied Sciences* 11(21), Special Issue: Trends and Challenges, 2021, 10453.

DOI: [org/10.3390/app112110453](https://doi.org/10.3390/app112110453)

- Briestenský M., Stemberk Josef, Littva J., Vojtko R.: Tectonic pulse registered between 2013 and 2015 on the eastern margin of the Bohemian Massif. *Geological Quarterly* 65:14, 2021, 1–7.

DOI: [10.7306/gq.1582](https://doi.org/10.7306/gq.1582)

- Klimeš J., Lu P.: Community-Based Landslide Risk Management in Contrasting Social Environments, Cases from the Czech Republic. In: Sassa K., Mikoš M., Sassa S., Bobrowsky P.T., Takara K., Dang K. (eds), *Understanding and Reducing Landslide Disaster Risk*. Vol. 1. Springer, Cham, 2021.

DOI: [org/10.1007/978-3-030-60196-6_46](https://doi.org/10.1007/978-3-030-60196-6_46)



The Department of Neotectonics and Thermochronology in 2021 addressed neo-tectonic processes in various tectonic regions and paleo-stress conditions in the Bohemian Massif, including the monitoring of fault structures: the marginal Sudeten, Mariánské Lázně, Železnohorské and Lusatia faults. Tectonic and geophysical research was also conducted in the US and India. In cooperation with other geoscience institutions, the department participated in research on slope deformations and the structural-tectonic development of sandstone reliefs in the Czech Republic and Poland. Recently-recruited foreign employees of the Institute expanded the scientific activities of the department via the study of neo-tectonics in the eastern foothills of the Himalayas and in the central part of Turkey.

The department was involved in international research on slope deformations and tectonic structures via the use of the following monitoring networks:

- Name: SlopeNet

Monitored issue: The monitoring of slope deformations, landslides and rockfalls.

Operator: IRSM (RENS programme).

Content: The geophysical and geotechnical monitoring of slope deformations, active involvement in international research and the taking over of co-responsibility for monitoring.

- Name: Network EU TecNet

Monitored issue: Tectonic structures in the EU.

Operator: IRSM (Czech/Geo programme).

Content: active involvement in the EU network, meter reading and service, and data evaluation.

Main output:

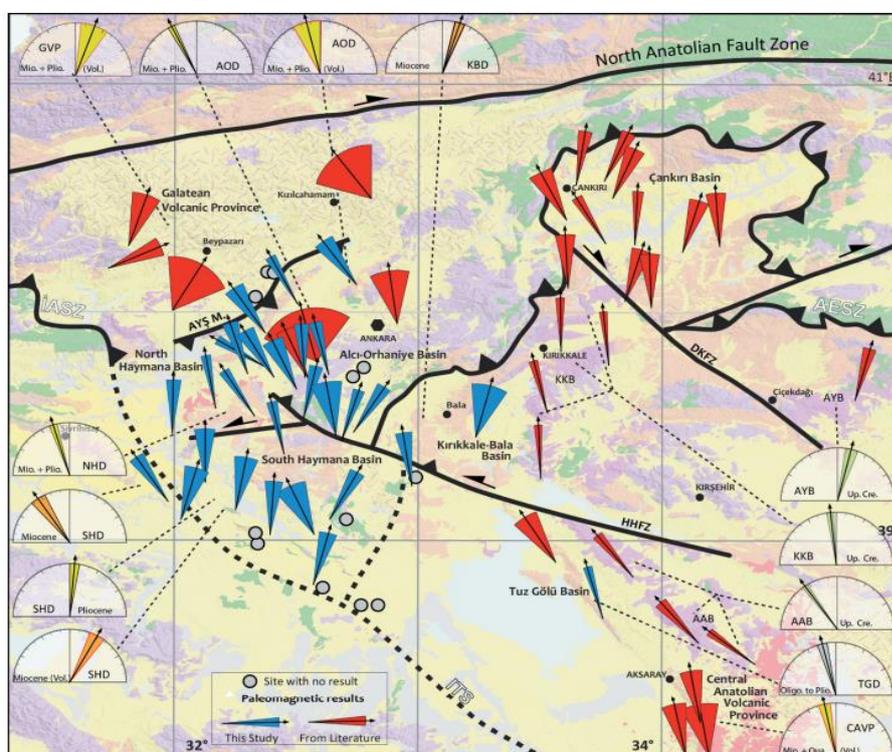
Neogene changes in the Neotethyan Suture Zone in Central Anatolia (Turkey).

Summary: The results of the study of paleo-magnetism at 40 new sites and 27 previously published sites provided evidence of repeated block rotations in central Anatolia since the Miocene. The results of the research indicate that the so-called “Neotethyan Suture Belts”, which today evince an orientation mainly in the east-west to east-southeast-west-northwest directions, had an approximately north-south orientation prior to the end of the Miocene.

Publication: Özkaptan M., Gülyüz E., Kaymakçı N., Langereis, C.G.: Neogene Restoration of Geometry of the Neotethyan suture zone in Central Anatolia (Turkey). International Geology Review, 2021.

DOI: 10.1080/00206814.2021.2010133

Illustration:



The Neogene rotation of blocks around a vertical axis in Central Anatolia, Turkey: the locations and results of the paleo-magnetic research (blue - results of this study, red - results according to data in the literature).

Further outputs:

- Özkaptan M., Gülyüz E., Uzel B., Özacar A.A., Langereis C.G., Kaymakçı, N.: Deformation in SW Anatolia (Turkey) Documented by Anisotropy of Magnetic Susceptibility Data. *Tectonics* 40, 2021, e2021TC006882. DOI: [org/10.1029/2021TC006882](https://doi.org/10.1029/2021TC006882)

- Sana H., Štěpančíková P., Szameitat A., Stemberk Jakub: Macro seismic Intensity Re-Evaluation of the 11 June 1895 Mid-Silesia, Poland, Earthquake. *Seismological Research Letters*, 92(2A), 2021, 1159–1167.

DOI: 10.1785/0220200359

- Břežný M., Pánek T., Braucher R., Šilhán K., Chalupa V., Lenart J., Tábořík P., Aster Team: Old but still active: >18 ka history of rock slope failures affecting a flysch anticline. *Landslides* 18 (1), 2021, 89–104.

DOI: 10.1007/s10346-020-01483-7

- Kadlec J., Klanica R., Tábořík P., Mrlina J., Valenta J., Kovacikova S., Hill G.J.: Reply to the Comment by Bábek et al. on Hypogenic Versus Epigenic Origin of Deep Underwater Caves Illustrated by the Hranice Abyss (Czech Republic)—The World's Deepest Freshwater Cave: Can the Hranice Abyss, the Deepest Underwater Cave in the World, Really Reach 1 km Depth? *Journal of Geophysical Research: Earth Surface* 126 (4), 2021, e2020JF005952.

DOI: 10.1029/2020JF005952



The Department of Seismotectonics addressed the study of natural seismic phenomena associated with the dynamics and tectonic development of structures in the earth's crust (especially in the upper part of the crust), the development of applications for the evaluation of geophysical measurements, and the development of monitoring devices and methodologies for seismic activity research purposes. The department continued its assessment of seismic hazards affecting nuclear power plants.

The department was involved in international research on seismic phenomena via the following monitoring networks:

- Name: Czech Regional Seismic Network.

Monitored issue: earthquakes in the Czech Republic and worldwide.

Operators: Academy of Sciences (AV CR): Institute of Geophysics (AV CR), IRSM, Institute of Geonics (AV CR); Institute of Earth Physics, Masaryk university; Charles University Faculty of Mathematics and Physics (Czech/Geo programme).

Content: a basic scientific infrastructure for the research of earthquakes, especially concerning long-term seismicity research in Europe and worldwide.

- Name: REYKJANET

Monitored issue: earthquakes in Iceland

Operators: Institute of Geophysics (AV CR) and IRSM (Czech/Geo programme).

Content: The detailed long-term international research of the seismic activity in Iceland.

- Name: MKNET

Monitored issue: earthquakes in the Lesser Carpathians.

Operators: IRSM; Institute of Geophysics, Earth Science Institute of the Slovak Academy of Sciences and Progseis s.r.o. (Czech/Geo programme).

Content: detailed research of this seismically active area; continuous recording and evaluation of the data.

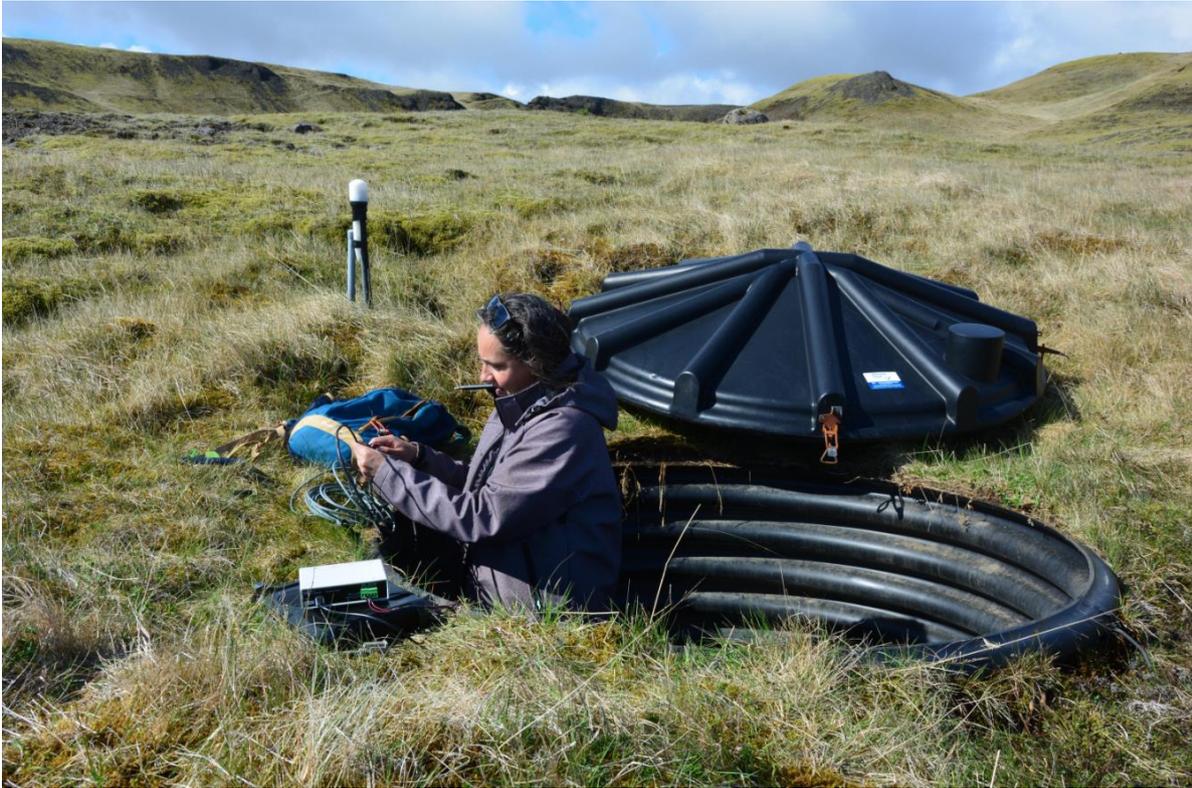


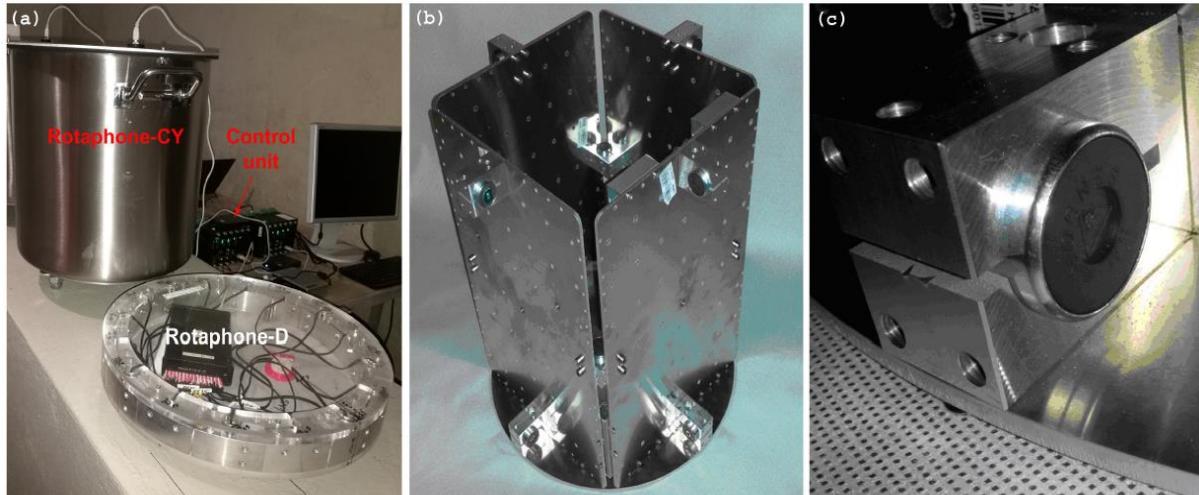
Illustration: Installation of a seismic station on the Reykjanes peninsula

Main outputs:

- Rotaфон-CY: The latest version of the Rotaфон model and the preliminary results from functional testing with active seismic sources.

Summary: Rotational seismology has developed rapidly over the last twenty years together with the introduction of new instruments in this field. In 2019, an international comparative test of seismographs designed for registering the rotational components of seismic waves took place in Germany aimed at comparing records from instruments based on different physical principles, the verification of the functioning of these instruments and their frequency ranges. The Rotaфон device received a very favourable evaluation as an extremely sensitive mechanical sensor system that is able to register up to nine seismic motion components; three displacement, three rotation and three soil deformation components can be measured simultaneously at one point. In contrast to more commonly used seismographs, this device allows for the comprehensive description of seismic movements in the vicinity of the measured point. The Rotaфон device is particularly suitable for the research of very weak local earthquakes. Further advantages of the newly-developed Rotaфон-CY device comprise a 32-bit AD converter and a protective jacket that shelters it from electromagnetic noise.

Publication: Brokešová J., Málek J., Vackář J., Bernauer F., Wassermann J., Igel H.: Rotaphone-CY: The Newest Rotaphone Model Design and Preliminary Results from Performance Tests with Active Seismic Sources. *Sensors* 21, 2021, 562.
DOI: [org/10.3390/s21020562](https://doi.org/10.3390/s21020562)

Illustration:

Rotafon-CY: (a) general view of the instrument compared to its predecessor, Rotafon-D and the control unit, (b) inner frame with geophones, (c) detail of the horizontal geophone attached to the inner frame.

- The analysis of injection-induced seismicity in the High Agri Valley (southern Italy) in the period 2016–2018 using cross-correlation enhanced detection.

Summary: The project involves the detection, localisation and subsequent interpretation of weak seismic events - tremors - in the High Agri Valley in connection with hydraulic operations at a nearby deep borehole used for the disposal of water that has been exposed to oil materials. The output of the project consists of a catalogue of 196 weak earthquakes that follow a south-west-oriented fault, which have been correlated over time with the injection parameters measured for the borehole: the pressure of the injected water and its volume.

(The High Agri Valley is an inland basin located in the southern Apennines that is oriented in the northwest-southeast direction; the area has one of the highest seismic potential levels in Italy: an earthquake that occurred in 1857 had a magnitude of Mw 7.0.)

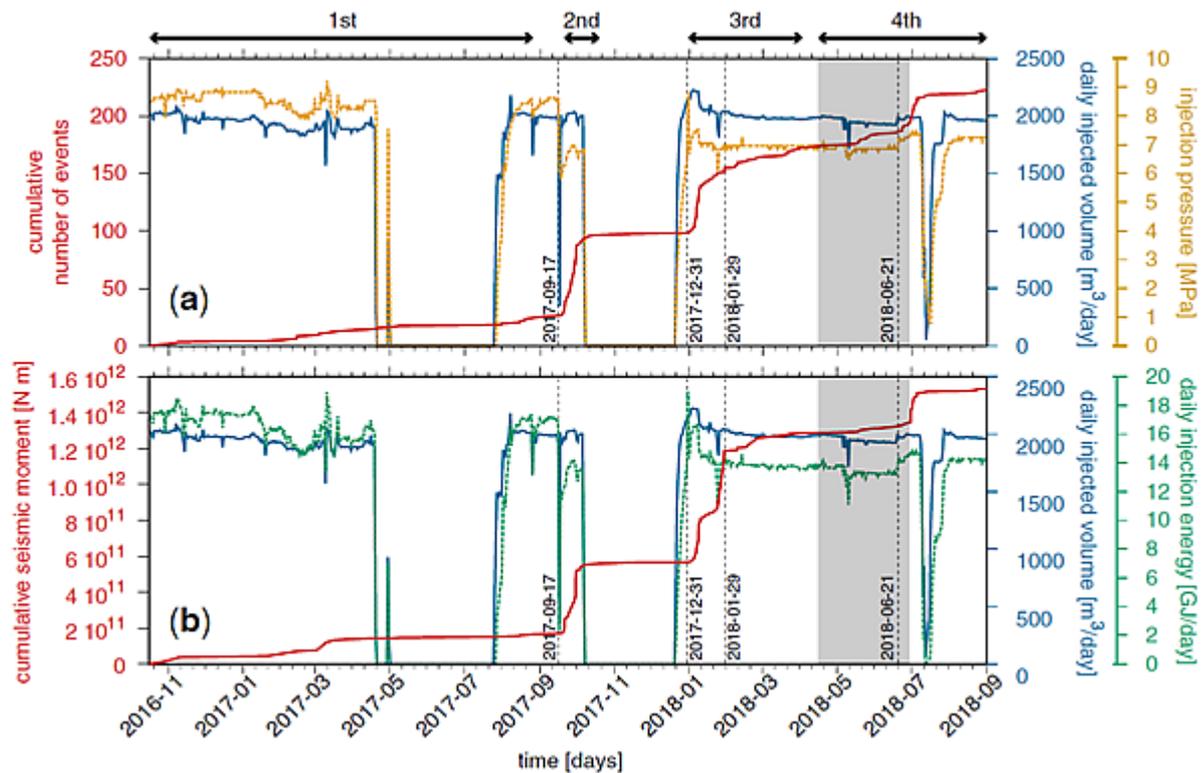
Publication: Stabile T. A., Vlček J., Wcisło M., Serlenga V.: Analysis of the 2016–2018 fluid-injection induced seismicity in the High Agri Valley (Southern Italy) from improved detections using template matching. *Scientific Reports* 11, 2021, 20630. DOI: 10.1038/s41598-021-00047-6

Illustration:

Temporal comparison of the detected seismic phenomena and the injection parameters:

(a): Comparison of the number of detected seismic events (red) with the hydraulic parameters – injection pressure (yellow) and water volume (blue).

(b): Comparison of the seismic energy release (seismic moment, red) with the injected hydraulic energy (green) and the water volume (blue).



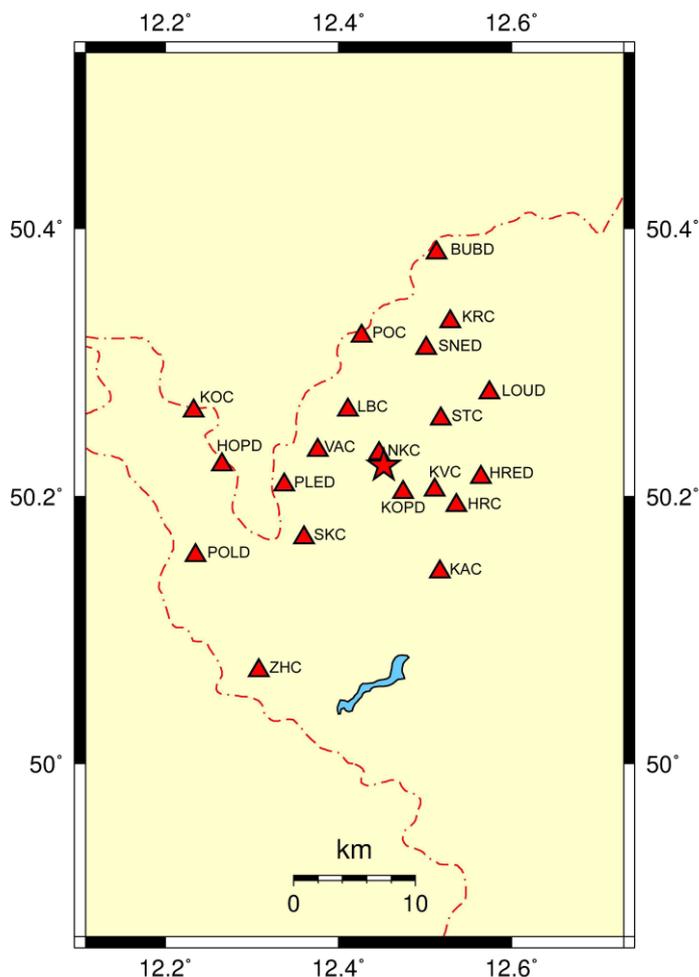
- Focal mechanisms of earthquakes in West Bohemia in May 2014: evidence of changes in the volume components.

Summary: West Bohemia features a large number of mineral springs and gas outbursts and is also an earthquake area. For example, the strongest earthquake in the area over the last thirty years occurred on 31 May 2014 (magnitude of $M_w \sim 3.8$), which was accompanied by two smaller earthquakes on the same day ($M_w \sim 2.9$ and 2.5). The focal mechanisms were monitored aimed at helping to clarify the nature of recorded earthquake swarms in West Bohemia. The research employed data from the WEBNET seismic network. The negative values detected for the full moment tensor volume components may have been connected to the closure of cracks during source processes.

Publication: Křížová D., Málek J.: Focal Mechanisms of West Bohemia, Central Europe, Earthquakes–End of May 2014: Evidence of Volume Changes. *Seismological Research Letters* 92(6), 2021, 3398–3415.
DOI: 10.1785/0220200389

Illustration:

The WEBNET seismic network stations are indicated by triangles with the data available for the 31 May 2014 earthquake. The epicentre of the strongest event is marked with an asterisk.



Further outputs:

- Ademović N., Demir V., Cvijić-Amulić S., Málek J., Prachař I., Vackář J.:
 Compilation of the seismic hazard maps in Bosna and Herzegovina. *Soil Dynamics and Earthquake Engineering* 141, 2021, 106500.
 Doi: 10.1016/j.soildyn.2020.106500

- Dal Moro G., Mirassi S., Rahnema H.: Cavity effect on Rayleigh dispersion and P-wave refraction, *Earthquake Engineering and Engineering Vibration* 20, 2021, 79–88.
 DOI: 10.1007/s11803-021-2006-y

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The Department of Geochemistry focused during the year on the research of the properties of rocks and materials employing surface chemistry, geochemistry and petrology methods, the mineral composition of rocks, and the processes involved in the formation and accumulation of organic matter in rocks. The study of the texture of porous rocks continued during the year. The research of environmental contamination included the analysis of the products of incomplete combustion and the investigation of the migration of toxic elements.

Follow-up research was conducted on the Blatná granite suite of the Central Bohemian magmatic complex that comprises principally biotitic granodiorites of the Blatná type and amphibolic-biotitic granodiorites of the Červená type.

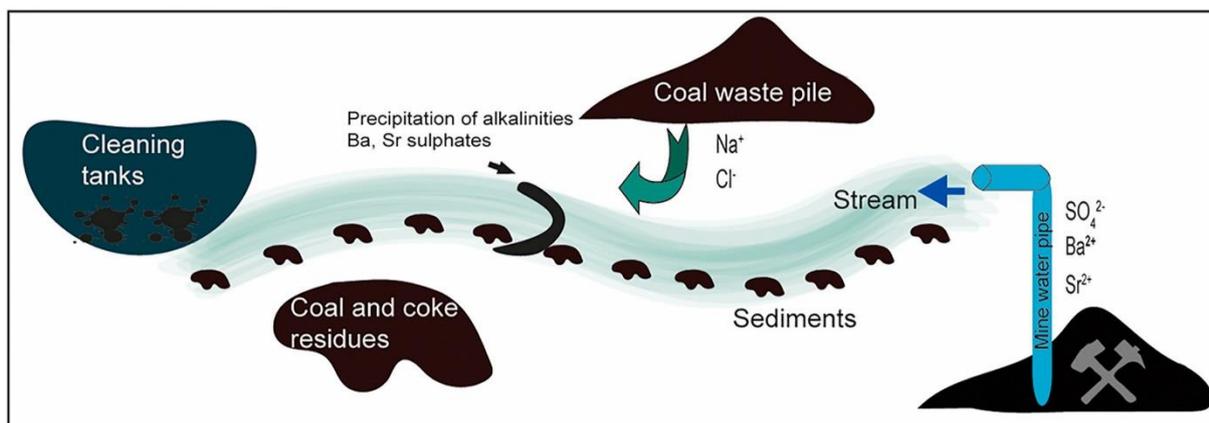
Main output:

Investigation of the influence of saline mine water on the fate of mineral elements and organic matter - a case study of the Upper Silesian coal basin.

Summary: Over time, the sediments around the former Lazy coal mine in the Upper Silesian coal basin have become enriched with variable amounts of Mn, Sr and Ba, the sulphates and feldspars of which have created significant mineral matrices. The enrichment of elements depends on the time from the deposition of sediments that are in contact with saline mine water. Such a system acts as a natural geochemical barrier, and the monitored sediments are beneficial in terms of the elimination of heavy metals.

Publication: Vöröš D., Římnáčová D., Medvecká L., Geršlová E., Díaz-Somoano M.: The impact of saline mine water on fate of mineral elements and organic matter: The case study of the Upper Silesian Coal Basin. *Chemosphere* 284, 2021, 131397. DOI: 10.1016/j.chemosphere.2021.131397

Illustration:



Environmental impact of sediments in the area of the former Lazy coal mine in the Upper Silesian coal basin. The situation at the site of the studied sediments: mine water in contact with a slag heap, the precipitation of mineral substances, the influence of coal and coke residues.

Further outputs:

- Suchý V., Borecká L., Pachnerová Brabcová K., Havelcová M., Světlík I., Machovič V., Lapčák L., Ovšonková A.Z.: Microbial signatures from speleothems: A petrographic and scanning electron microscopy study of coralloids from the Koněprusy Caves (the Bohemian Karst, Czech Republic). *Sedimentology* 68, 2021, 1198–1226.

DOI: org/10.1111/sed.12826

- Kříbek B., Bičáková O., Sýkorová I., Havelcová M., Veselovský F., Knésl I., Mészáros N.: Experimental pyrolysis of metalliferous coal: A contribution to the understanding of pyrometamorphism of organic matter and sulfides during coal waste heaps fires. *International Journal of Coal Geology* 245, 2021, 103817.

DOI: 10.1016/j.coal.2021.103817

- Krausová I., Mizera, J., Řanda Z., Chvátíl D., Krist P.: Instrumental Photon Activation Analysis with Short-Time Irradiation for Geochemical Research. *Minerals* 11, 2021, 617, 1–13.

DOI: [org/10.3390/min11060617](https://doi.org/10.3390/min11060617)

- Řimnáčová D., Vöröš D., Medvecká L., Geršlová E.: Textural properties and organic matter in sediments from a hard coal mine landfill. *Paliva* 13, 2021, 30–34.

DOI: [10.35933/paliva.2021.02.01](https://doi.org/10.35933/paliva.2021.02.01)



The Department of Composite and Carbon Materials focused principally on the study of the properties of collagen-based materials for potential use in the healthcare sector concerning two main research areas, the first of which concerns collagen replacements and patches for use in vascular surgery. The mechanical properties of specially-prepared collagen hydrogels are optimised applying nanofibrous reinforcement based on organic and synthetic polymers, or via the using the activity of cells, which are able to transform them into structurally and mechanically advantageous materials under either static or dynamic conditions. The second research area concerns resorbable arterial bandages based on a composite material composed of a synthetic copolymer nanofibrous reinforcement combined with a collagen matrix. The aim is to reduce the flow of blood through the arterial bed and to protect the arterial wall from pathological deformation and rupture. In addition, the department conducted the monitoring of the delamination properties of the human aorta and, more broadly, questions surrounding the propagation of cracks within, and the disruption of, arteries. These phenomena occur in clinical practice during the dissection and rupture of arteries, both of which are life-threatening conditions. Research was also conducted on the physicochemical parameters of collagen masses, the properties of which are influenced by various parameters, especially the water content, as well as the effects of high pressures and a mono-energetic beam of accelerated electrons.

The research of special composites focused on the development of composite materials with a partially pyrolysed polysiloxane matrix reinforced with basalt fibre fabrics. The use of these materials was investigated for the production of light but strong roof coverings to replace asbestos cement. The frost resistance tests of these newly-developed materials confirmed that they meet the standard requirements for roof coverings.

The evaluation of mechanical properties is ongoing, as is the preparation of experimental equipment for the modelling of climatic loading, which allows for a high number of freezing cycles. An experimental study was completed during the year of the thermomechanical analysis of the mechanical properties of thermoset precursors *in situ* during the pyrolytic transformation of siloxane polymers into ceramics, and phenolic resins into carbon materials. Further, the research continued of the temperature transformations of composite matrices during the production of composites and under operational loading.

Main output:

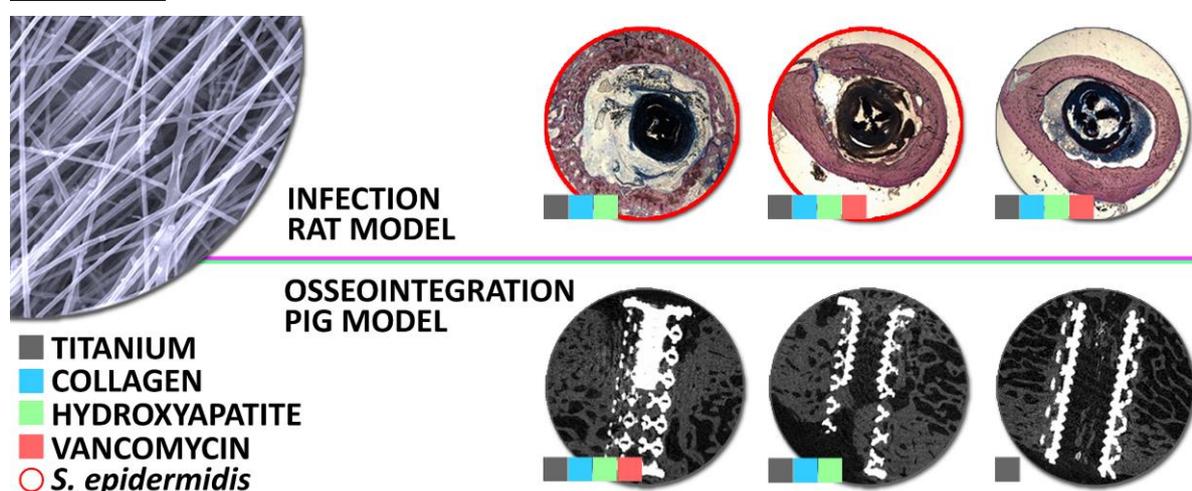
- The surface layer of implants for the prevention of infection and the enhancement of osseointegration.

Summary: Collagen-hydroxyapatite layers with vancomycin, prepared via electrospinning directly onto the surface of 3D printed titanium implants were studied in detail. The resulting layer prevents the destruction of bone associated with the *S. epidermidis* infection and enhances the rate of osseointegration. This nano-structural surface modification, which has been tested under both *in vitro* and *in vivo* conditions, represents a promising option for the surface treatment of metal implants.

Publication: T. Suchý, L. Vištejnová, M. Šupová, P. Klein, M. Bartoš, Y. Kolinko, T. Blassová, Z. Tonar, M. Pokorný, Z. Sucharda, M. Žaloudková, F. Denk, R. Ballay, Š. Juhás, J. Juhásová, E. Klapková, L. Horný, R. Sedláček, T. Grus, Z. Čejka, Z. Čejka, K. Chudějová, J. Hrabák: Vancomycin-Loaded Collagen/Hydroxyapatite Layers Electrospun on 3D Printed Titanium Implants Prevent Bone Destruction Associated with *S. epidermidis* Infection and Enhance Osseointegration. *Biomedicines* 9, 2021, 531, 1–21.

DOI:10.3390/biomedicines9050531.

Illustration:



The arrangement of collagen-calcium phosphate nanolayers with vancomycin directly applied to the surface of modelled printed titanium alloy implants for *in vivo* testing. Collagen-calcium phosphate nanolayers with vancomycin combine the ability to prevent bone infection with the ability to promote enhanced osseointegration. The ability to prevent bone infection was investigated using a rat model (top) that simulated the clinically relevant bacterial contamination of bone during surgery using a clinical isolate of *Staphylococcus epidermidis*. The ability to enhance osseointegration was investigated using a growth-stopped minipig model (bottom).

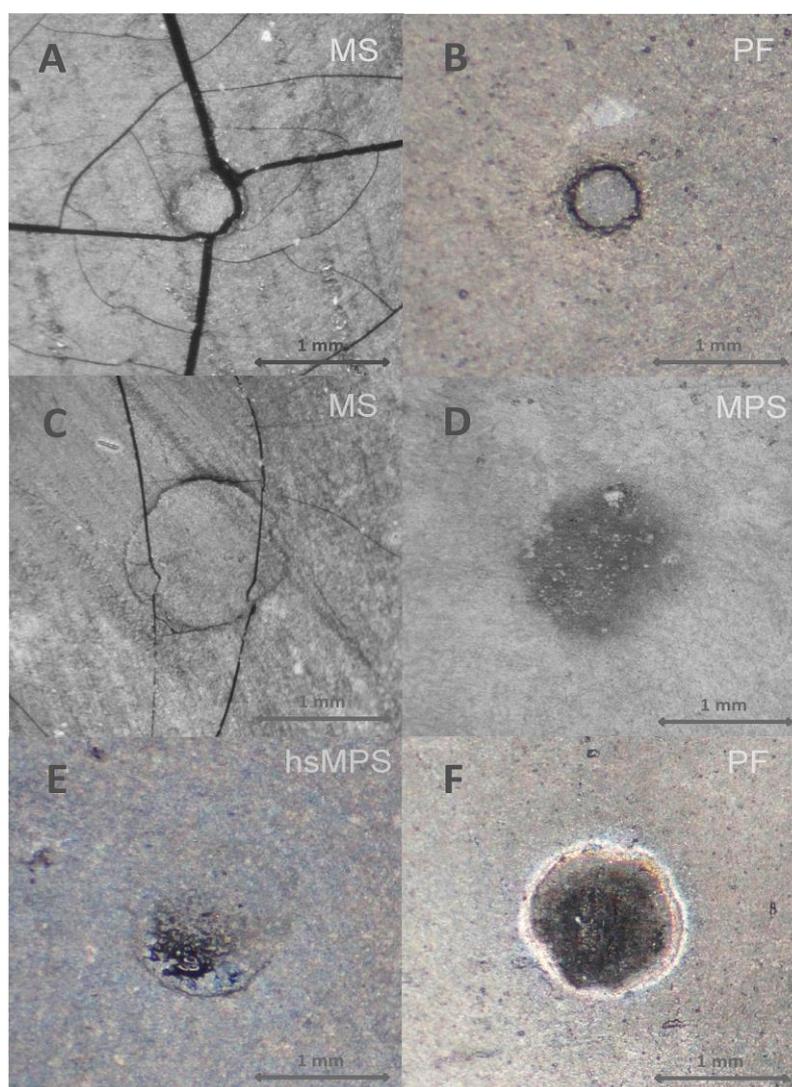
- The transformation of the mechanical properties of, and dimensional changes to, pre-ceramic polymers observed *in situ* during the preparation of ceramics

Summary: The thermomechanical analysis of the pyrolysis processes of four structurally differing types of cross-linked pre-ceramic resins (methylsiloxane, methylphenylsiloxane, methylphenylsiloxane hardened with hydrosilylation and phenol formaldehyde) revealed that they undergo significant softening and subsequent hardening. This is accompanied by significant dimensional changes, with the cross-linking of the thermoset microstructure greatly limiting the relaxation of stress via

plastic deformation. The thermomechanical method of cyclic indentation *in situ* was selected for the conducting of a detailed analysis of these processes, whereby a cylinder with a flat, spherical or ball end was used as the indenter. This method allowed for the determination of the simultaneous temperature characteristics of elastic, viscoelastic and residual deformations and total shrinkage during the preparation of ceramic materials.

Publication: Černý M., Chlup Z., Strachota A., Brus J., Schweigstillová J., Rýglová Š., Bičáková O.: In-situ measurement of mechanical properties and dimensional changes of preceramic thermosets during their pyrolysis conversion to ceramics using thermomechanical analysis. *Ceramics International* 47, 2021, 23285–23294. DOI:10.1016/j.ceramint.2021.05.041

Illustration:



Indentations on the final ceramic materials following experiments applying thermomechanical analysis under pyrolysis conditions, as shown by means of light microscopy after cyclic loading from 20 to 1300°C: A) methylsiloxane (MS) precursor – spherical-ended indenter; B) phenol-formaldehyde (PF) precursor – ball-ended indenter; C) MS precursor – flat-ended indenter; D) methylphenylsiloxane (MPS) precursor – flat-ended indenter; E) hydrosilylation-cured methylphenylsiloxane (hsMPS) precursor – flat-ended indenter; F) PF precursor – flat-ended indenter.

Further outputs:

- Rýglova Š., Braun M., Hříbal M., Suchý T., Vöröš D.: The proportion of the key components analysed in collagen-based isolates from fish and mammalian tissues processed by different protocols. *Journal of Food Composition and Analysis* 103, 2021, 104059.

DOI: 10.1016/j.jfca.2021.104059

- Suchý T., Bartoš M., Sedláček R., Šupová M., Žaloudková M., Martynková G.S., Foltán R.: Various simulated body fluids lead to significant differences in collagen tissue engineering scaffolds. *Materials* 14, 2021, 4388, 1–17.

DOI: 10.3390/ma14164388

- Braun M., Rýglová Š., Suchý T.: Determination of glycosaminoglycans in biological matrices using a simple and sensitive reversed-phase HPLC method with fluorescent detection. *J. Chromatogr. B Anal. Technol. Biomed. Life Sci.* 1173, 2021, 122626.

DOI: 10.1016/j.jchromb.2021.122626

- Grus T.; Suchý T.; Šupová M.; Chlup H.; Hartinger J.: Sandwich collagen foam for the controlled release of active substances and the method for the preparation thereof. Patent no. 308 862. Industrial Property Office of the Czech Republic, 2021.



The Department of the Structure and Properties of Materials continued the research of socially-necessary technologies during the year, namely (a) the modelling of glass melting processes and the development of new melting facilities, as well as the monitoring of inhomogeneities in glass melts at high temperatures, the vitrification of radioactive waste, and the preparation of glass that is permeable to infrared radiation and the characterisation thereof; (b) the use of beach sand and various types of stone dust as geo-polymeric matrix fillers for use in the construction industry; (c) the restoration of the original ceramic tiles in the church of St. John of Nepomuck in Žďár nad Sázavou; (d) the technical-economic aspects of the use of Power-to-Gas technology for energy storage purposes; (e) the technology for the splitting of waste cross-linked polyethylene into hydrocarbon raw materials.

Main outputs:

- Beach sand – an alternative filler for metakaolin-based geopolymers.

Summary: Beach sand is unsuitable for use as a filler in concrete due to its salinity and generally uniform grain size; however, it has been successfully applied as an

alternative filler material in geopolymer composites. The results confirmed the increasing tendency of both the bending strength and plain pressure values over time up to maxima of 9.95 MPa and 64.1 MPa, respectively. Infrared analysis subsequently proved the formation of geopolymer bonds. The results thus open up the possibility of using beach sand in coastal areas as a new local source of materials for simple construction projects.

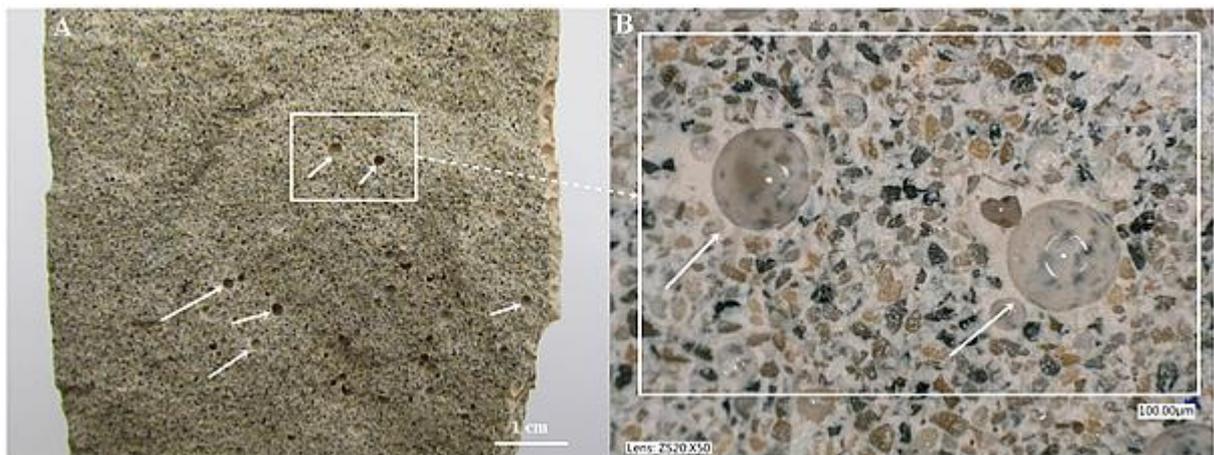
Publication: Perná I., Novotná M., Šupová M., Hanzlíček T.: Beach Sand – an Alternative Filler in Metakaolin-Based Geopolymers. *Journal of Materials in Civil Engineering* 33 (4), 2021, 04021017-1 – 04021017-6.

Doi: 10.1061/(ASCE)MT.1943-5533.0003641

Illustration:



Beach sand: A – general view, B – detail.



Geopolymer composite filled with beach sand: A – general view, B – detail.

 - A method for the melting of glass in a glass melting furnace and the glass melting furnace for the application of the method.

Summary:

This method for the melting of glass in a glass melting furnace involves the melting of glass batches in the conversion region by means of electrodes and/or burners; the melt obtained is then homogenised in the homogenisation region, wherein an effective uniform or spiral flow is established in the free level melt section. The batch has a

movable limit, which is set at a maximum of 50% of the length of the homogenisation region (preferably to 20-30%) by means of the setting of the energy ratios at k_1 and k_{1J} . The k_1 ratio comprises the proportion of energy supplied by the electrodes and burners to the conversion region to the total energy supplied to both regions. The k_{1J} ratio comprises the ratio of the energy supplied by the electrodes to the conversion region to the total energy supplied to the conversion region by the electrodes and burners. The values of both the k_1 and k_{1J} ratios are within the range 0–1, the ratios $k_1 = 0.8–1$ and $k_{1J} = 0.5–1$ are most suitable. The range of ratios $k_1 = 0.90–0.945$ and $k_{1J} = 0.6–0.75$, at which the maximum critical melting capacity of 399–588 tonnes/day is attained, is regarded as the optimal. The project also includes a detailed description of the glass melting furnace used for the application of this method.

Publication: Němec L., Jebavá M., Cincibusová P., Budík P., Tonarová V.: A method for the melting of glass in a glass melting furnace and the glass melting furnace for the application of the method. Patent no. 309094, Industrial Property Office of the Czech Republic, 2021.

Further outputs:

- Perná I., Novotná M., Řimnáčová D., Šupová M.: New metakaolin-based geopolymers with the addition of different types of waste stone powder. *Crystals* 11(8), 2021, 983, 1–11.
DOI:10.3390/cryst11080983
- Straka P.: A comprehensive study of Power-to-Gas technology: Technical implementations overview, economic assessments, methanation plant as auxiliary operation of lignite-fired power station. *Journal of Cleaner Production* 311, 2021, 127642.
DOI: 10.1016/j.jclepro.2021.127642
- Moško J., Pohořelý M., Skoblia S., Fajgar R., Straka P., Soukup K., Beňo Z., Farták J., Bičáková O., Jeremiáš M., Šyc M., Meers E. (2021): Structural and chemical changes of sludge derived pyrolysis char prepared under different process temperatures. *Journal of Analytical and Applied Pyrolysis* 156, 105085.
DOI: 10.1016/j.jaap.2021.105085
- Kostka P., Yatskiv R., Grym J., Zavadil J.: Luminescence, up-conversion and temperature sensing in Er-doped $\text{TeO}_2\text{-PbCl}_2\text{-WO}_3$ glasses. *Journal of Non-Crystalline Solids* 553, 2021, 120287.
DOI: 10.1016/j.jnoncrysol.2020.120287
- Bošák O., Kubliha M., Kostka P., Minarik S., Domankova M., Le Coq D.: Electrical and Dielectric Properties of $\text{Sb}_2\text{O}_3\text{-PbCl}_2\text{-AgCl}$ Glass System. *Russian Journal of Electrochemistry* 57(7), 2021, 681–687.
DOI: 10.1134/S1023193521070041
- Ueda N., Vernerová M., Kloužek J., Ferkl P., Hrma P., Yano T., Pokorný R.: Conversion kinetics of container glass batch melting. *Journal of the American Ceramic Society* 104(1), 2021, 34–44.
DOI: 10.1111/jace.17406
- Marcial J., Pokorný R., Kloužek J., Vernerová M., Lee S., Hrma P., Kruger A.: Effect of water vapor and thermal history on nuclear waste feed conversion to glass. *International Journal of Applied Glass Science* 12(1), 2021, 145–157.
DOI: 110.1111/ijag.15803

- Lee S., Cutforth D., Mar D., Kloužek J., Ferkl P., Dixon D., Pokorný R., Hall M., Eaton W., Hrma P., Kruger A.: Melting rate correlation with batch properties and melter operating conditions during conversion of nuclear waste melter feeds to glasses. *International Journal of Applied Glass Science* 12(3), 2021, 398–414.
DOI: 10.1111/ijag.15911
- Luksic S., Pokorný R., Hrma P., Varga T., Rivers E., Buchko A., Kloužek J., Kruger A.: Through a glass darkly: In-situ x-ray computed tomography imaging of feed melting in continuously fed laboratory-scale glass melter. *Ceramics International* 47(11), 2021, 15807–15818.
DOI: 10.1016/j.ceramint.2021.02.153
- Abboud A., Guillen D., Hrma P., Kruger A., Klouzek J., Pokorny R.: Heat Transfer from Glass Melt to Cold Cap: Computational Fluid Dyamics Study of Cavities beneath Cold Cap. *International Journal of Applied Glass Science* 12(2), 2021, 233–244.
DOI: 10.1111/ijag.15863
- Jebavá M., Hrbek L., Cincibusová P., Němec L.: Energy distribution and melting efficiency in glass melting channel: Effect of configuration of heating barriers and vertical energy distribution. *Journal of Non-Crystalline Solids* 562, 2021, 120776.
DOI: 10.1016/j.jnoncrysol.2021.120776
- Straka P., Bičáková O., Čimová N.: Low-temperature treatment of waste PET. *Paliva* 13(1), 2021, 1–9.
DOI: 10.35933/paliva.2021.01.01

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All the Institute's scientific departments continued to make efforts to popularise the results of their activities during the year either at exhibitions, as part of the AS CR Science and Technology Week or via lectures and articles written with the public in mind accompanied by visual documentation (see section 7 and the illustrative photograph).

Illustration of the popularisation of the activities of Institute: Seismological research in Iceland.



Photo: Department of Seismotectonics archive

3. Research projects conducted by the Institute's scientific departments in 2021

Projects financed by the Grant Agency of the Czech Republic:

- Infrared transmissive glass based on heavy metal oxides.
- The mechanics of arterial delamination and crack propagation.
- The radiolytic alteration of organic matter in a uranium-bearing medium.
- The study of methods for the modification of the mechanical properties and structures of collagen masses.
- The influence of post-genetic changes in granites on their resistance to weathering processes in historical buildings.
- Physical processes associated with swarm seismicity along the interfaces of tectonic plates in southern Iceland and earthquake swarms in western Bohemia/Vogtland.
- Stress- and hydraulic field-controlled weathering and erosion of granular rocks.
- Quaternary tectonic activity in West Bohemia and its relationship to volcanism.

Projects financed by the Technology Agency of the Czech Republic:

- Interactive map of the seismic hazard in the Czech Republic.
- Natural seismicity as a tool in the search for geothermal energy sources.
- The geological environment and mineral resources.
- Geophysics, geotechnics, geomaterials, geothermal energy in practice.
Subprojects:
 - o The potential for the cracking of waste polyethylene into a mixture of hydrocarbons: the technological verification of a heat treatment method.
 - o The development of equipment for the coating of thin wires with biodegradable polymers from a solution.
 - o Partially pyrolysed composites as a light roofing material – the verification of climatic resistance and the optimisation of a suitable textile reinforcement material.
 - o A seismic beacon - a system for detecting temporal changes in the properties of rock masses.
 - o A system for the automated evaluation of records obtained from networks.
 - o The optimisation of a system for the automated measurement, processing and interpretation of electro-resistance monitoring.

Projects financed by the Ministry of Education, Youth and Sports and the Ministry of Health:

- The preparation and characterisation of amorphous materials for infrared applications.
- Bioartificial cardiovascular patches and vascular replacements based on porcine collagen reinforced nano/microfibres remodelled via stem cells in bioreactors.

- Biomechanically defined absorbable materials for cardiovascular surgery.
- Delimitation of the zone of partial healing of zirconium fission tracks via the fission track and micro-Raman spectroscopy methods: the key to understanding thermochronological dating, the properties of zirconium-based materials and the thermal maturity of hydrocarbon source rocks.

Projects with foreign participation:

- Representation of the Czech Republic in the management of INQUA (International Union for Quaternary Research).
- Representation of the Czech Republic in the management of ICL (International Consortium on Landslides) through the Centre of Excellence.
- The six-component continuous monitoring of seismic swarms and other earthquakes in the Long Valley Caldera area, California.

4. Cooperation with universities

With respect to university teaching activities during the year, the staff of the IRSM provided 225 hours of teaching for bachelor courses and 134 hours for master's courses in the summer semester and 267 hours for bachelor, 172 hours for master's and 28 hours for doctoral courses in the winter semester. The institute trained 11 doctoral students, 1 of whom from abroad. The staff of the department taught several courses in various fields during the year, especially at the Charles University (Faculty of Science, Faculty of Mathematics and Physics and the Faculty of Medicine in Pilsen), the CTU in Prague (Faculty of Mechanical Engineering and the Faculty of Nuclear Sciences and Physical Engineering), the University of Chemical Technology (Faculty of Chemical Technology), the Masaryk University in Brno (Faculty of Natural Sciences), the University of Ostrava (Faculty of Natural Sciences) and the University of South Bohemia, České Budějovice (Faculty of Education), as well as at the Universidad Nacional de Córdoba Argentina - Facultad de Ciencias Exactas, Físicas y Naturales.

The Institute shares two facilities with universities, i.e. with the Faculty of Natural Sciences of Charles University and the University of Chemical Technology in Prague. The staff of the Institute participated during the year in 4 doctoral study boards, namely at the University of Chemical Technology in Prague, the Technical University of Ostrava and Charles University (Faculty of Natural Sciences).

The implementation continues of the "Agreement on mutual cooperation concerning the implementation of the Physics of the Earth and Planets doctoral study programme" concluded with the Faculty of Mathematics and Physics of Charles University involving both full-time and combined forms of study.

5. Contractual services

Contracts:

1) Commissioned by: Asron s.r.o.

Contract: The heat treatment of waste including the evaluation thereof.

Summary: The experimentation showed that ERVOeco's plastic and municipal waste processing technology has the potential to transform such waste into products with a high utility value, especially into oils that can be used for both energy and non-

energy purposes. In the case of non-energy use, such oils are able to provide a source of valuable liquid hydrocarbons and solvents, precursors for the production of certain synthetic polymers, siloxanes for construction purposes, and the essential oxygen compounds, i.e. alcohols, ketones and esters of the higher fatty acids.

Application: The processing of plastic and municipal waste.

2) Commissioned by: Devro, s.r.o.

Contract: The analysis of collagen mass samples.

Summary: The evaluation of three series of collagen mass samples for the technological requirements of Devro, s.r.o. A qualitative chemical analysis was conducted in order to evaluate the samples for the content of water, fats, glycosaminoglycans, amino acids and nitrogen; the analysis also included the evaluation of the secondary structure of the collagen samples.

Application: The optimisation of the technological processes at Devro, s.r.o.

3) Commissioned by: Devro, s.r.o.

Contract: The preliminary analysis of collagen casing samples.

Summary: Potential methods for the determination of differences in selected chemical properties that serve for the characterisation of the surroundings of defects were determined and described via the analysis of collagen casing samples with defects applying the infrared spectrometry method.

Application: The optimisation of the technological processes at Devro, s.r.o.

4) Commissioned by: UJP Praha a.s.

Contract: The pre-hydridation of Zr1Nb alloy samples.

Summary: The identification of the effect of absorbed hydrogen on the corrosion properties of the Zr alloy of a nuclear fuel coating tube involved the study of a set of 105 test samples with the required hydrogen concentrations of 1000, 600 and 300 ppm. The hydridation of the zirconium alloy was performed via the application of an original method developed by the IRSM employing sorption microbalances that makes use of the accuracy and sensitivity of the weighing system, the potential for its evacuation to high vacuum rates, the potential to vary the temperature and pressure conditions and the ability to terminate hydridation once the required weight gain has been attained.

Application: The prediction of the corrosion behaviour of Zr alloy-coated tubes as the first protection layer for nuclear fuel.

5) Commissioned by: DIAMO state enterprise, uranium mining and processing plant.

Contract: The determination of the pore distribution in rocks.

Summary: The aim of the contract was to determine the distribution of pores in rocks in the meso-, macro- and coarse pore range with respect to 60 structurally intact samples of sedimentary rocks using the mercury porosimetry method. The results of the porosimetry analysis proved, based on the comparison of two analyses of each sample, the very good degree of homogeneity of the analysed sedimentary rocks. The porosity in 36 samples ranged on average up to 11%, with 12 samples exhibiting slightly lower values of, on average, around 8%. The highest porosities, up to 30%, were recorded for 12 samples. The results of the analysis clearly indicated the significance of the most frequently represented radius, which corresponded to the predominance of the size of the pores according to their classification in the analysed rocks. Samples with predominantly mesoporous, macroporous and coarsely porous characters were identified.

Application: The determination of the transport parameters of the Turonian and Cenomanian collector transition.

6) Commissioned by: Equis, s.r.o.

Contract: The measurement of the VS30 parameter at selected locations in the Jaslovské Bohunice and Mochovce nuclear power plants.

Summary: Geophysical surveys were conducted at the Jaslovská Bohunice and Mochovce nuclear power plant sites, during which the VS30 parameter was determined in the lithotypes selected by the client. (Note: VS30 is the average seismic velocity of the shear wave from the surface to a depth of 30 metres. This parameter characterises the seismic response of a given site for the purposes of the simplified design of earthquake-resistant buildings and forms a part of the construction codes of most countries.)

Application: Calculation of the seismic threat to the critical infrastructure in the vicinity of nuclear power plants.

7) Commissioned by: ČEZ a.s.

Contract: Seismic risk calculations for the Dukovany and Temelín nuclear power plants

Summary: The project concerned the determination of probabilistic seismic hazard curves, uniform response spectra and seismic hazard disaggregation for the Dukovany and Temelín nuclear power plants. The calculations, which were summarised in the form of two reports, were made in preparation for an International Atomic Energy Agency (IAEA) mission planned for 2022.

Application: The safety of nuclear power plants.

8) Commissioned by: The Czech Radioactive Waste Repository Authority (SÚRAO).

Contract: The monitoring of the activity of the brittle structures of the Bukov URF and the Rožná mine - continuous monitoring and evaluation.

Summary: The parameters of brittle structures and brittle failure were measured and evaluated for the Bukov underground research facility and the Rožná Mine. The results were subsequently summarised in a technical report by Stemberk J., Briestenský M., Hartvich F., Fučík Z. (2021): The monitoring of the activity of brittle structures at the Bukov URF and the Rožná mine – continuous monitoring and evaluation 3. – MS SÚRAO, TZ 571/2021, 2021, 30 pages.

Application: The disposal of radioactive waste.

9) Commissioned by: The Czech Radioactive Waste Repository Authority (SÚRAO).

Contract: The monitoring of the seismic phenomena at the radioactive waste repository located in the Richard mine near Litoměřice

Summary: The results of long-term continuous seismic monitoring conducted at two seismic stations in the radioactive waste repository located in the Richard mine were presented and commented upon in the form of three reports compiled as a contribution towards ensuring the seismic safety of the repository.

Application: The seismic safety of the repository.

9) Commissioned by: Statotest s.r.o.

Contract: The determination of the accuracy characteristics of an accelerometer sensor: the laboratory testing and compensation of the systematic measurement errors of the sensor developed by Statotest, s.r.o.

Summary: The accuracy characteristics were determined of the Statotest accelerometer sensor designed for the measurement and analysis of linear and angular acceleration. The results were summarised in the form of a technical report and further published in the following symposium: Balek J., Klokočník P.: Development of a low-cost inclination sensor based on MEMS accelerometers. In: World Multidisciplinary Earth Sciences Symposium (WMESS 2021) 5–9 September 2021, Prague, Czech Republic.

Application: Shock, movement, impact and vibration characteristics.

10) Commissioned by: GasNet Služby, s.r.o.

Contract: Geophysical survey of the bedrock beneath the Vltava river bed using the multi-electrode resistance method for the purposes of the construction of the REKO VTL DN 150 Řež u Prahy.

Summary: The depth and structure of the bedrock beneath the bed of the Vltava river was determined via the conducting of a geophysical survey. The results are intended for the future construction of utility networks near the town of Řež u Prahy.

Application: The construction of utility networks.

Cooperation with public administration authorities:

Commissioned by: The Czech Highways Authority.

Contract: The ongoing solution of the issue of the slope stability and safety of the D8 highway in connection with the activities of the IRSM's representative in the D8 Motorway Monitoring Council (RAMO).

Expertise:

1) Commissioned by: The Czech Highways Authority.

Expertise: The analysis of the planned construction of sections of highways and Class I roads and the potential threat from slope deformations in 2021. Stage 1: Mapping and the field verification of landslides in the areas of the planned constructions and their surroundings.

2) Commissioned by: The Czech Highways Authority.

Expertise: The analysis of the planned construction of sections of highways and Class I roads and the potential threat from slope deformations in 2021. Stage 2a/2021 – Geophysical survey of selected slope deformations and the compilation of a map of the susceptibility to the occurrence of slope deformations along the D11 highway.

3) Commissioned by: The Czech Highways Authority.

Expertise: The analysis of the planned construction of sections of highways and Class I roads and the potential threat of slope deformations in 2021. Stage 2b/2021 – Geophysical survey of selected slope deformations and the mapping of the threat of their occurrence.

4) Commissioned by: The Czech Highways Authority.

Expertise: The determination of the location and extent of a municipal waste dump in the areas of numbers 1105/1 and 1105/2 of the cadastral territory of Velká Chuchle (729213) and the registration of title deed no. 28.

5) Commissioned by: The City of Cheb

Expertise: The geodetic monitoring of a potentially unstable section of a local asphalt road with a length of approximately 40 m adjacent to building no. 72/22. The assessment of the extent of the instability was submitted to the authorised person.

6. International cooperation

The Institute participated during the year in 8 international projects, and in 7 bilateral agreements on scientific cooperation with foreign partners. The staff of the Institute worked in 8 international scientific organisations, in three cases in official management positions.

International projects:

- 1) INTER-VECTOR – Representing the Czech Republic in the management of the International Consortium on Landslides through the Centre of Excellence (2019 – 2021).
- 2) INTER-VECTOR – Representing the Czech Republic in the management of the International Union on Quaternary Research - INQUA at the TERPRO commission level (2020 – 2022).
- 3) LTA-USA19083 – Six-component continuous monitoring of seismic swarms and other earthquakes in the region of the Long Valley Caldera, California (2019 – 2022).
- 4) ICCP – Identification of Dispersed Organic Matter. International Committee for Coal and Organic Petrology, 2021.
- 5) ICCP – The evaluation of self-heating on coals of different rank via optical microscopy. International Committee for Coal and Organic Petrology, 2021.
- 6) MSM100462001 – Vanadium migration in coal regions: Sorption of vanadium on selected clay minerals (2020-2021).
- 7) Sigma-2 – R & D project about seismic hazard and ground motion, 2021.
- 8) European initiative Adria array – Understanding Active Deformation of the Adriatic Plate and its Margins.
- 9) Norway Funds: Natural Seismicity as a Prospecting and Monitoring tool for geothermal energy extraction

Official positions in the membership of international organisations:

- 1) Doc. Ing. Jaroslav Kloužek, CSc.: International Commission on Glass, Technical Committee No. 18 – Glass melting. Chairperson, term of office: 2016 – 2023.
- 2) RNDr. Petra Štěpančíková, PhD: International Union for Quaternary Research, Commission on Terrestrial Processes, Deposits, and History. Vice president, term of office: 2019 – 2023.
- 3) RNDr. Josef Stemberk, CSc., RNDr. Jan Klimeš, PhD.: International Consortium on Landslides. Member of the Board, term of office: 2013 – 2023.

Bilateral cooperation with foreign partners:

- 1) Instituto Geofísico del Peru.

Theme: The monitoring of tectonic movements.

- 2) Instituto Nacional de Investigación en Glaciares y Ecosistemas de las Montaña (Peru).
Theme: The evaluation of the danger of slope movements around the village of Rampac Grande, Cordillera Negra, Peru.
- 3) Instytut Geofizyki Polskiej Akademii Nauk.
Theme: The research of tectonic movements and slope deformations in the Svalbard archipelago.
- 4) Uniwersytet Wrocławski.
Theme: The research of the structural-geological conditions and construction of the Broumov/ Góry Stolowe table mountains; arctic and permafrost research.
- 5) Naturhistorisches Museum Wien.
Theme: The research of active tectonics in caves in the Eastern Alps.
- 6) Johannes-Guttenberg Universität Mainz.
Theme: The radiometric dating of active tectonics in karst caves.
- 7) University of Memphis.
Theme: The research of local seismicity.

International Advisory Board

In 2021, the International Advisory Board was kept informed of the institute's activities:

- Prof. Vladimir Yudin

Institute of macromolecular compounds RAS
199004 Saint-Petersburg, Bolshoy pr. 31,
Russia

- Prof. Dr. Manfred Joswig

Goethestr. 25, D-40237 Düsseldorf
Germany

- Dr. Yann Klinger

Tectonique - Bureau 208
Institut de Physique du Globe - CNRS UMR7154
Université de Paris
1, rue Jussieu
75238 Paris cedex 05, France
France

- Dr. Rouwen Lehné

Hessisches Landesamt für Umwelt und Geologie (HLNUG)
Dezernat G1 – Geologische Grundlagen
Rheingastr. 186
65203 Wiesbaden
Germany

- Prof. Dr. Kimon Christanis

Department of Geology
University of Patras
University Campus
GR-265.04 Rio-Patras

Greece

7. Popularisation and public education activities

- 1) Exhibition: Unstable subsoil - Landslides, lives and perspectives. Museum of the City of Ústí nad Labem, IRSM; J. E. Purkyně University in Ústí nad Labem, 23 November 2021 – 3 April 2022.
- 2) Interview with Dr. Jan Klimeš: The new Landslide Tracker application enables public involvement in the research of slope deformations in the Czech Republic. Czech Television Studio 6, 26 May 2021.
- 3) Article in the AS CR magazine: Landslide Research, magazine A/Science and research 01/2021, 11 March 2021.
- 4) Presentation: There is no pore like a pore. Experiments on and the teaching of the theory of pores, porous materials, natural resources and the cleaning of pollutants from the environment. IRSM, Department of Geochemistry, Prague, 4 November 2021.
- 5) Excursion: Environmental technology. Tours of the equipment and instrumentation of the Laboratory of Environmental Technologies for professionals and the general public. IRSM, Department of the Structure and Properties of Materials, Prague, 13 and 26 January, 2, 11 and 25 February, 26 May and 21 August 2021.
- 6) Czech Television, i-broadcast: “Wandering camera” programme. A walk through the Czech Republic of the future – Bioengineering. The third part of a summer special of this popular TV programme. Czech Television filmed a short report with the staff of the Department of Composite and Carbon Materials.
- 7) Article for the public - materials and technology (see the example below):

Science in action: [The revolutionary processing of waste cross-linked polyethylene](#)



The popularity of cross-linked polyethylene (PEX) continues to increase. A number of products are made from PEX including plumbing and distribution systems, heat pumps and ventilation equipment. But how to deal with PEX waste, the disposal of which is subject to strict regulations? Its incineration is banned and, after three years, it cannot even be disposed of in landfill sites. An answer has been found by the IRSM of the Czech Academy of Sciences.



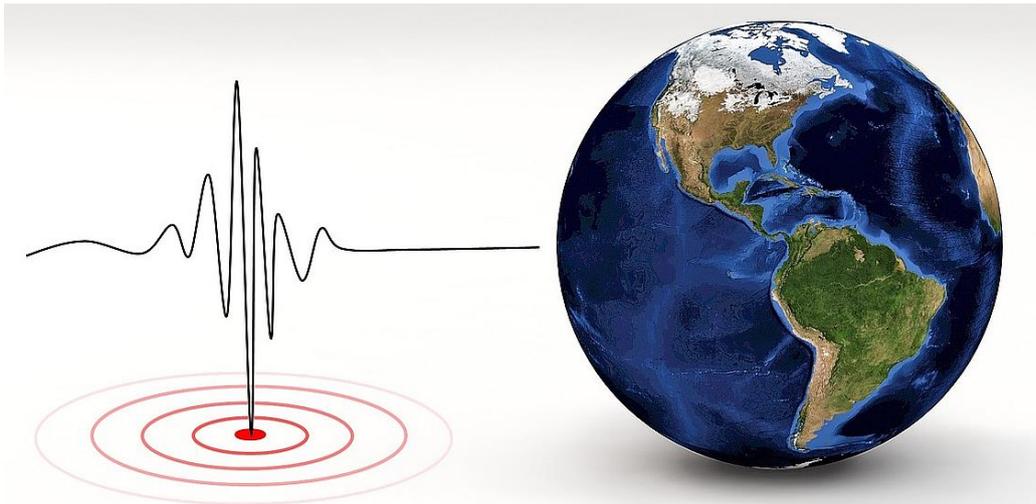
Waste cross-linked polyethylene

Original and useful

The innovation consists of the **processing of such plastic waste into oils that can be used for various applications** or be added to other hydrocarbon mixtures. Since the proposed technology works within a low-temperature range (i.e. up to 500°C, preferably 450-470°C), the **process is not burdened with high energy consumption**; moreover, the gases produced can be used to heat the processing unit, so that the unit is, to a certain extent (potentially even largely), energy self-sufficient. The technology will be beneficial for industrial companies involved in the production of cables, pipes, heat pumps, underfloor heating systems, boilers, ventilation equipment, etc., which are faced with the issue of disposing of waste PEX during the production process. Furthermore, it will also benefit refineries in terms of the processing of oil residues.

8) Article for the public - geosciences (see the example below):

Science in action: [Seismic beacon](#)



Small local seismic beacons will provide for the early warning of earthquakes and landslides caused, for example, by changes in groundwater levels. They will be used in the safety management of dams and oil and gas mines, nuclear power plants, nuclear waste storage/disposal facilities, water management systems and urban agglomerations.

Innovation. Seismic beacons will enable the highly sensitive and stable measurement of changes within rocks over long time periods, which is not possible using currently available measuring devices. The technology is based principally on the non-linear effects of seismic waves and allows for the detection of hitherto unmeasurable quantities, such as the attainment of the critical stress level prior to an earthquake. The beacon consists of a transmitter, receiver and processing software. The transmitter continuously generates very stable monochromatic seismic waves with a constant amplitude, which are transmitted to depth, pass through the rocks under study and are subsequently detected by seismic stations. The receiver comprises several groups of seismic stations set up in a special arrangement that allow for the detection of even very weak waves from the beacon. The processing algorithm makes use of the linear and non-linear properties of seismic waves to detect changes in the rock mass. A small-scale seismic beacon with a range of several kilometres, which can be used to monitor groundwater levels, is currently under construction. It will also serve for trial and presentation purposes for parties that are interested in the product.

Main advantages. • The measurement of stress changes in rocks at depth, including the attainment of the critical level • The detection of magma movements. • The measurement of the water saturation of rocks and changes in the groundwater level. • The one order of magnitude higher measurement sensitivity compared to current solutions. • Continuous 24/7 measurement. • New methods for the interpretation of the measured data that enable in-time warnings.

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8. Network monitoring

Monitoring 1

Monitoring network: SlopeNet:

Monitoring of slope deformations, landslides and rock falls.

Operator: IRSM, RENS programme.

Activities: the geophysical and geotechnical monitoring of slope deformations with co-responsibility for monitoring.

Monitoring 2

Monitoring network: Network EU TecNet:

The 3D monitoring of tectonic structures in the EU.

Operator: IRSM, Czech/Geo programme.

Activities: meter readings, service and data evaluation.

Monitoring 3

Monitoring network: Czech Regional Seismic Network:

Earthquake monitoring in Europe and worldwide.

Operators: Institute of Geophysics AS CR, IRSM, Institute of Geonics AS CR, Institute of Earth Physics, Masaryk university and the Charles University Faculty of Mathematics and Physics, Czech/Geo programme.

Activities: basic scientific earthquake research infrastructure, especially concerning long-term seismicity research in Europe and worldwide.

Monitoring 4

Monitoring network: MKNET:

Earthquake monitoring in the Lesser Carpathians.

Operators: IRSM, the Earth Science Institute of the Slovak Academy of Sciences, Progseis s.r.o., Czech/Geo programme.

Activities: the continuous recording and evaluation of detailed research data on selected seismically active areas.

Monitoring 5

Monitoring network: REYKJANET:

The monitoring of earthquakes in Iceland.

Operators: Institute of Geophysics AS CR and IRSM, Czech/Geo programme

Activities: detailed long-term international research in a seismically active area of Iceland.

Monitoring 6

Monitoring network: Landslides, rockfalls and ground currents as recorded in the media since 2011:

The emergence and reactivation of slope deformations in the Czech Republic.

Operator: IRSM, NASA programme.

Activities: determination of the location and the time of occurrence of landslides, and the damage they cause.

Monitoring 7

Monitoring network: TecNet:

The monitoring of slow movements along tectonic faults.

Operator: IRSM, Czech/Geo programme.

Activities: the tracking of seismic tectonic movements along faults.

Monitoring 8

Monitoring network: Geonas.

The tracking of the movements of GNSS fixed points.

Operator: IRSM, Czech/Geo programme.

Activities: the gathering of data for the monitoring of tectonic movements.

9. Published periodicals

1) *Acta Geodynamica et Geomaterialia*, Vol. 18, Nos. 1–4, 2021, ISSN 1214-9705 (Print); 2336-4351 (On-line). Impact-factor journal published on a quarterly basis.

Database monitoring: Science Citation Index Expanded; Journal Citation Reports/Science Edition.

2) *Ceramics-Silicates*, Vol. 65, Nos. 1–4, 2021, ISSN 0862-5468 (Print); ISSN 1804-5847 (On-line). Impact-factor journal published on a quarterly basis. Database monitoring: Science Citation Index; Materials Science Citation Index; the Engineering Index (Published by Engineering Information Inc.).

IV. Evaluation of other activities

The Institute has no other activities. For the evaluation of other activities, see Section III, point 5.

V. Information on measures to remedy management deficiencies and the report on how the said measures imposed in the previous year have been implemented

The IRSM had no management deficiencies in 2021 or in the previous year.

VI. Financial information on items that are significant in terms of the assessment of the economic situation of the Institute that may affect its future development

See the financial statements and auditor's report in the appendices to this report.

VII. Envisaged development of the Institute's activities

The scientific activities of the IRSM will continue to develop in accordance with global research trends, with an emphasis on publishing and teaching and popularisation activities. With respect to scientific research and the enhancement thereof, the Institute will continue to recruit from the doctoral study programmes mentioned previously in this report. The certification of the Institute's researchers will continue aimed at enhancing the quality of their work. The performance of researchers will be rewarded by increases in remuneration and the adjustment of working hours. The Institute's equipment will be expanded, updated and developed on a continuous basis and the staff will be provided with the appropriate training.

VIII. Environmental protection activities

In response to the needs of society as a whole, the assessment of alternative fuels will continue and the Institute will continue to be involved in developing plastic and municipal waste treatment methods, the treatment and transformation of sludge from wastewater treatment plants into fertilisers and the advancement of radioactive waste disposal technologies. A further significant contribution comprises the development of a municipal waste processing method in cooperation with two industrial companies. Conditions are in place for IRSM employees to recycle their waste and hazardous waste is disposed of ecologically by authorised companies. Pest control is performed on a yearly basis.

IX. Further sections of the Annual Report:

Institute of Rock Structure and Mechanics of the CAS, V Holešovičkách 94/41, 182 09 Prague 8, Czech republic					
Profit and loss statement					
ID number 67985891		Balance as at 31. 12. 2021			According to Decree No. 504/2002 Coll.
(in Czech Crowns, the comma separates two decimal places)					
Item		Row	Activities		
Number	Designation		Main activity	Supplementary activity	Total
A	A. Expenses				
A.I	I. Consumed purchases and purchased services	002	20 949 141,26	1 111 712,38	22 060 853,64
A.I.1	1. Consumption of material, energy and other non-inventory items	003	8 613 308,43	559 704,06	9 173 012,49
A.I.3	3. Repairs and maintenance	005	2 300 555,95	11 803,90	2 312 359,85
A.I.4	4. Travel expenses	006	2 217 637,51	246 453,08	2 464 090,59
A.I.5	5. Representation costs	007	19 321,05	0	19 321,05
A.I.6	6. Other services	008	7 798 318,32	293 751,34	8 092 069,66
A.II	II. Changes in inventories by their own activities and activation	009	113,63	0	113,63
A.II.8	8. Activation of material, goods and interior services	011	113,63	0	113,63
A.III	III. Total personnel expenses	013	63 664 053,00	1 428 852,00	65 092 905,00
A.III.10	10. Wages and salaries	014	46 733 719,00	1 065 985,00	47 799 704,00
A.III.11	11. Statutory social insurance	015	15 395 826,00	342 270,00	15 738 096,00
A.III.13	13. Statutory social expenses	017	1 534 508,00	20 597,00	1 555 105,00
A.IV	IV. Total taxes and fees	019	65 643,00	1 500,00	67 143,00
A.IV.15	15. Taxes and fees	020	65 643,00	1 500,00	67 143,00
A.V	V. Total other expenses	021	3 907 606,62	1 116 121,74	5 023 728,36
A.V.16	16 Contractual fines, delay interests, other fines and penalties	022	2 833,00	0	2 833,00
A.V.19	19. Exchange rate losses	025	77 569,25	0	77 569,25
A.V.22	22. Other expenses	028	3 827 204,37	1 116 121,74	4 943 326,11
A.VI	VI. Total depreciation expenses, sold assets, addition and utilization to reserves and adjustments	029	16 077 964,14	0	16 077 964,14
A.VI.23	23. Depreciation expenses of fixed assets	030	14 577 964,14	0	14 577 964,14
A.VI.27	27. Addition and utilization to reserves and adjustments	034	1 500 000,00	0	1 500 000,00
A.VIII	VIII. Total income tax	037	203 690,00	0	203 690,00
A.VIII.29	29. Income tax	038	203 690,00	0	203 690,00
	Total expenses	039	104 868 211,65	3 658 186,12	108 526 397,77
B	B. Revenues				
B.I	I. Total operating grants	041	87 037 731,99	0	87 037 731,99
B.I.1	1. Operating grants	042	87 037 731,99	0	87 037 731,99
B.III	III. Revenues of own services and merchandise	047	493 032,88	4 303 180,73	4 796 213,61
B.IV	IV. Total other revenues	048	18 378 762,72	0	18 378 762,72
B.IV.5	5. Contractual fines, delay interests, other fines and penalties	049	37 684,60	0	37 684,60
B.IV.7	7. Interest income	051	42 697,27	0	42 697,27
B.IV.8	8. Exchange rate gains	052	1 536,49	0	1 536,49
B.IV.9	9. Settlement of funds	053	818 157,29	0	818 157,29
B.IV.10	10. Other revenues	054	17 478 687,07	0	17 478 687,07
B.V	V. Total revenues from assets sold	055	1 495,00	0	1 495,00
B.V.13	13. Revenues from disposals of materials	058	1 495,00	0	1 495,00
	Total revenues	061	105 911 022,59	4 303 180,73	110 214 203,32
C	C. Profit / Loss before tax	062	1 246 500,94	644 994,61	1 891 495,55
D	D. Profit / Loss after tax	063	1 042 810,94	644 994,61	1 687 805,55

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