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

ANNUAL REPORT 2020

Translation

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

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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 Kriegsman, (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:	Doc. 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 6 organisational communications during 2020. Meetings were held on a monthly basis between the Institute's management and heads of department.

- Contracts were concluded for 1 new Czech Grant Agency (GA CR) project, for 3 Technology Agency of the Czech Republic (TA CR) projects and for 4 projects commissioned by other institutions (the Ministry of Education, Youth and Sports and the Ministry of Health).

- The publication activities of the Institute's researchers were assessed in the form of a competition and the results subsequently published.

- New IRSM election rules were submitted and approved by the Board of the Institute.

- The IRSM Research Activity Programme for the period 2020-2024 was submitted and approved by the Board of the Institute

- New rules for the management of earmarked funds were submitted and approved by the Board of the Institute

- The certification verification of all the Institute's researchers was conducted.

- A total of 4 construction projects were realised during the year: the construction of an elevator between buildings A and B, the reconstruction of building A, the reconstruction of the centrifuge facility for the location of an electron microscope, and the repair of the roof cladding in building E. The reconstruction of the centrifuge facility for the location of an electron microscope project will continue into 2021. Ten orders for new scientific instruments were realised (a Hitachi centrifuge, a mercury porosimeter, an electron microscope with sample preparation equipment, ArcGIS software, a grinding mill bowl, an agitator, LabView software, a lyophiliser with accessories, an LH 15/13 oven and a specific conductivity measuring kit), of which 3 instruments (the Hitachi centrifuge, the mercury porosimeter and the electron microscope with sample preparation equipment) were co-financed by the Academy of Sciences of the Czech Republic. Furthermore, a contract was fulfilled for the supply of an economic information system which was co-financed by the Academy of Sciences of the Czech Republic.

Board of the Institute:

The Board of the Institute held four regularly-scheduled meetings during 2020:
2 June, 20 July, 12 November and 15 December, of which the 15 December meeting took place in the form of a video conference due to the Covid-19 situation

- 2 June: the activities of the IRSM during the first half of 2020 and the ongoing international evaluation of the IRSM for the period 2015 – 2019 were discussed, and the fulfilment of the 2019 budget and the financial statements and auditor's report for 2019 were approved. In addition, the draft budget of the IRSM for 2020 was discussed.

- 20 July: the Board set the criteria for the evaluation of researchers in the forthcoming certification verification process and the documentation that research staff will be required to submit to the Certification Commission. In addition, the Board discussed the documentation for the application for remuneration support for post-doctoral students provided by the founding institution.

- 12 November: The IRSM Research Programme for the period 2020 – 2024 was approved and issues surrounding the submission of research projects provided by the European Research Council (ERC) were discussed. In addition, the date was set for the agreement of the final version of the IRSM Research Activity Programme for the period 2020 – 2024.

- 15 December: The Council discussed the managing director's report on the activities of the IRSM during the second half of 2020, the management of the Institute in 2020, information on the ongoing international evaluation of the Institute for 2015-2019 and the report on the Institute's budget for 2021. The Institute will provide financial support to staff for the submission of research projects provided by the European Research Council. Due to the Covid-19 pandemic situation, the Institute's cooperation with the IRSM International Advisory Council will be conducted via the provision of the English version of the IRSM annual report for 2020; the Institute anticipates a written response from, or a video discussion with the members of the council. A directive concerning the creation of earmarked funds, i.e. the "Principles for the Management of Earmarked Funds valid from 2021" document was approved.

Supervisory Board:

In accordance with the Rules of Procedure, the Supervisory Board met twice in 2020, and discussed a total of 4 issues via letter. The Board was provided with the financial results of the Institute, its 2019 Annual Report and the budget for 2020.

The first meeting of the Board, held on 5 June 2020, included the verification and approval of the minutes of the February 2019 meeting, a discussion on the disbursement of the IRSM budget in 2019 and the outlook for 2020, and a discussion on, and the noting of, the financial and auditor's reports for 2019. Further, the Board discussed and approved the Report on the Activities of the IRSM Supervisory Board for 2019 and the IRSM 2019 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 8 December 2020 partly in the form of a video conference, the Board verified and approved the minutes of the January 2020 meeting and postal votes nos. 1/2020, 2/2020, 3/2020 and 4/2020. The Board further discussed the disbursement of the budget in 2020 and the outlook for 2021, and discussed the IRSM's 2020 activities and results as presented by the managing director including the planned certification verification of the Institute's researchers.

During 2020, the Board discussed and approved 4 draft resolutions by letter with concern to:

1) the granting of prior written consent to a proposal for the purchase of a new economic information system in accordance with the respective tender procedure (adopted on 23 January 2020),
2) approval of a proposed amendment to the Rules of Procedure of the IRSM Supervisory Board allowing for remote meetings of the Board (adopted on 14 September 2020),
3) the appointment of ACONTIP, s.r.o., as the IRSM's financial auditor for 2020 (accepted on 4 November 2020)
4) prior written consent to the purchase of high-cost scientific equipment (an electron microscope and a sample preparation laboratory) in accordance with the respective tender procedure (adopted on 12 November 2020).

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 necessary research of materials. The Institute comprises 4 geoscience and 2 material and engineering-oriented scientific departments, in addition to administrative and support departments. The Institute's scientific activities are conducted in accordance with recommendations provided by its International Advisory Council.

- Geoscientific research:

Rock mass research focusing on the conditions for the creation of natural and induced geodynamic phenomena and activities underway in the upper layer of the earth's crust that threaten the stability of the earth's surface aimed at minimising the adverse impacts thereof. Particular attention was devoted to the development of reliable and accurate methods for the monitoring of slope phenomena, especially landslides, and the prediction of their occurrence and development. Further, research focused on the monitoring and study of the transmission of seismic waves in various rock environments, the monitoring and analysis of slope and tectonic movements, the study of paleo seismic activity along active faults in the Czech Republic and the paleontological conditions of the Bohemian Massif, as well as the research of other geochemical and textural topics.

- Materials research:

The study of raw materials and organic and inorganic materials focusing on their origin, properties, involvement in anthropogenic processes and applications in the fields of geology, ecology and production technologies; the preparation and research of the properties of collagen materials for use in vascular surgery, the study of the properties of bone bioapatite for use in medical applications; the development of hybrid composites with reinforcement for high-temperature applications; the modelling of smelting processes, the development of new smelting facilities, the vitrification of radioactive waste; the preparation of infrared translucent glass that is permeable to infrared radiation and the characterisation thereof; the preparation of new geopolymer composites aimed at reducing the ecological burden; the development of technologies for the heat treatment of biomass, sludge and plastic waste mixtures.

The Institute achieved a number of significant research results during the year via international research cooperation and cooperation with both domestic and foreign universities, other institutes of the Academy of Sciences of the Czech Republic and various industrial companies (TARPO, s.r.o., DEKONTA, a.s., etc.). Two examples are presented below:

1) Shifts in volcanic structures as measured in the fault area of the San Andrés massive landslide, El Hierro, Canary Islands. A multidisciplinary study that is

providing a comprehensive overview of the behaviour of giant landslides on volcanoes.

Summary: A multidisciplinary study that is providing a comprehensive overview of the behaviour of giant landslides on volcanoes. A combination of three scientific disciplines, i.e. microstructural analysis, structural geological mapping and cosmogenic dating have proved the existence of historical shifts (reactivations) in isolated areas of a massive collapse of the studied volcano. Moreover, for the first time, a siliceous layer has been identified in the volcanic rock structure caused by the frictional melting of rock during a giant slope movement.

The results were achieved in cooperation with three major European scientific institutions:

Universität Wien, Abteilung für Geodynamik und Sedimentologie;
CNRS – Université de Lorraine, Le Centre de Recherches Pétrographiques et Géochimiques; Instituto Geográfico Nacional, Centro Geofísico de Canarias, Santa Cruz de Tenerife, Spain.

Illustration: example of a giant landslide - the collapse of a volcano on the island of El Hierro, Canary Islands.

Publication:
Blahůt Jan, Mitrovic-Woodell Ivanka, Baroň Ivo, René Miloš, Rowberry Matt, Blard Pierre-Henri, Hartvich Filip, Balek Jan, Meletlidis Stavros (2020). Volcanic edifice slip events recorded on the fault plane of the San Andrés Landslide, El Hierro, Canary Islands. Tectonophysics 776, 228317.
ISSN: 0040-1951, DOI: 10.1016/j.tecto.2019.228317

2) Technology for the processing of dried sewage sludge for the production of energy.

Summary: the technology includes a special apparatus and the methodology for the use of sludge generated via the biological anaerobic treatment of municipal sewage in wastewater treatment plants. Sludge from effluent treatment plants, following dewatering and drying, provides a raw material for the production of both gas for heating and dried sludge that can be used as a fertiliser with a high phosphorus

content. The patent also includes an innovative approach to the connection of the heating gas produced to the gas management system of treatment plants.

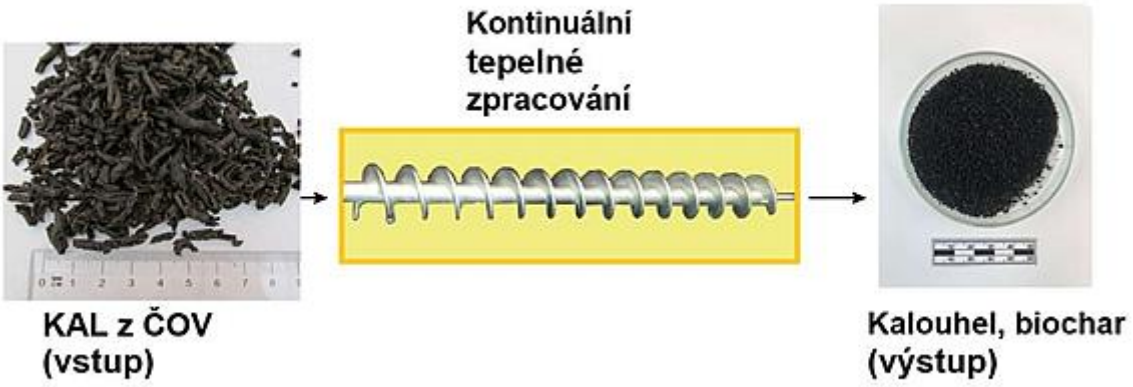

Illustration: sludge from wastewater treatment plants is converted in a continuous heat treatment reactor into a sludge for use as a fertiliser with a high phosphorus content.

The results were achieved in cooperation with the Institute of Chemical Process Fundamentals, Academy of Sciences of the Czech Republic, the Institute of Chemical Technology (ICT) in Prague and the industrial company TARPO s.r.o.

Output:
Patent no. CZ 308 451 (2020)
Pohořelý Michael, Picek Ivo, Skoblia Siarhei, Beňo Zdeněk: Methodology and equipment for the energy processing of dried sewage sludge. Patent holders: Institute of Chemical Process Fundamentals, Academy of Sciences of the Czech Republic, Prague 6; ICT in Prague, Prague 6; TARPO s.r.o., Kněževes; IRSM, Prague 8.

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 disciplines and two on materials and engineering topics:

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

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

The department of Geochemistry's sorption and porosimetry analysis laboratory is shared with the Faculty of Science of Charles University. Similarly, the department of Structure and Properties of Materials' inorganic materials laboratory is shared with the University of Chemical Technology, Prague.

All the Institute's departments are involved in AV21 Strategy research programmes, and the staff are involved in teaching at various universities.

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.

Output:

The calculation of sediment volumes in a landslide-dammed lake employing electrical resistance tomography and sonar profiles (sound navigation ranging) of the lake.

Summary: the calculation procedure is based on the use of an innovative geophysical resistance profiling application that records measurements from the lake surface in a series of profiles. Using this and other methods, i.e. sonar depth measurements, sediment contribution monitoring and conductivity measurements, it was possible to reconstruct the original relief of the bottom of the Mladotice lake immediately following the landslide and to calculate the volume of sediments and the sedimentation rate, thus allowing for the estimation of the future development of the lake. The most interesting result was that the sedimentation rate has decreased significantly over the last 20 years, suggesting that the lake may survive much longer than previously expected.

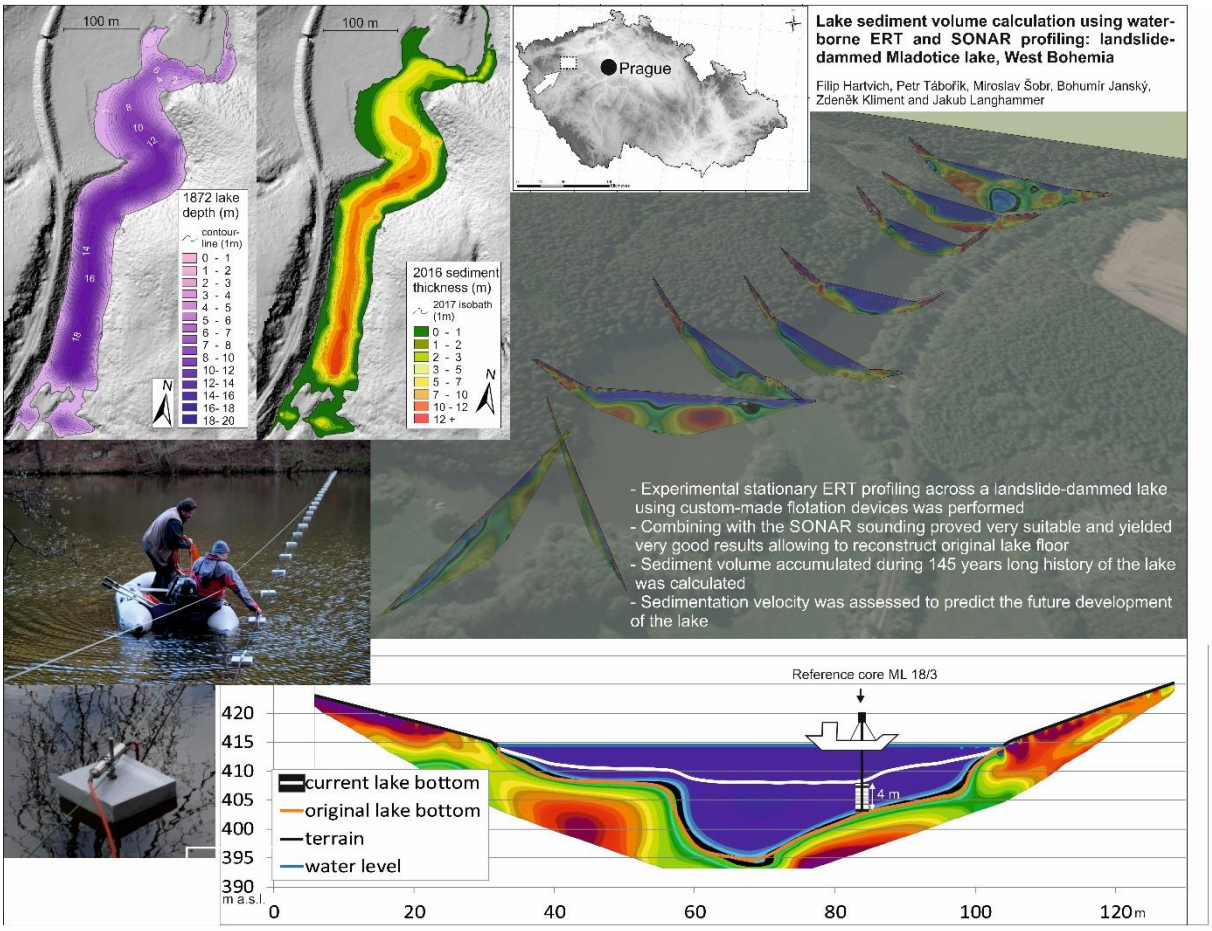

Illustration: top left: depths of the lake in 1872; sediment layer thicknesses in 2016; bottom: current lake bottom and original lake bottom, terrain and water levels.

Publication:
Hartvich F., Tábořík P., Šobr M., Janský B., Kliment Z., Langhammer J. (2020).

Landslide-dammed lake sediment volume calculation using waterborne ERT and SONAR profiling. *Earth Surface Processes and Landforms* 45, 3463–3474. DOI: org/10.1002/esp.4977.

Further outputs:

- Baroň I., Sokol L., Melichar R., Plan L. (2019). Gravitational and tectonic stress states within a deep-seated gravitational slope deformation near the seismogenic Periadriatic Line fault, *Engineering Geology* 261 (11), 105284. DOI: 10.1016/j.enggeo.2019.105284
- Vilímek V., Klimeš J, Tito-Mamani R.V., Bastante A.J., Astete F.V., Champi P.Z.M. (2020). Contribution of the collaborative effort of the Czech WCoE to landslide risk reduction at the Machupicchu World Heritage Site, Peru. *Landslides* 17, 2683–2688. DOI: org/10.1007/s10346-020-01509-0
- Emmer A., Klimeš J., Hölbling D., Abad L., Draebing D., Skalák P., Štěpánek P., Zahradníček P. (2020). Distinct types of landslides in moraines associated with the post-LIA glacier thinning: Observations from the Kinzl Glacier, Huascarán, Peru. Science of the Total Environment 739, 139997. DOI: org/10.1016/j.scitotenv.2020.139997
- Šolcová A., Jamrichová E., Horsák M., Pařil P., Heiri O., Květoň J., Křížek M., Hartvich F., Hájek M., Hájková P. (2020): Abrupt vegetation and environmental change since the MIS 2: a unique paleorecord from Slovakia (Central Europe). *Quaternary Science Reviews* 230, 106170. DOI: org/10.1016/j.quascirev.2020.106170
- Klimeš J., Müllerová H., Woitsch J., Bíl M., Křížová B. (2020). Century-long history of rural community landslide risk reduction. *International Journal of Disaster Risk Reduction* 51, 101756. DOI: org/10.1016/j.ijdrr.2020.101756
- Blahůt J., Mitrovic-Woodell I., Baroň I., René Miloš, Rowberry M., Blard P-H., Hartvich F., Balek J., Meletlidis S. (2020). Volcanic edifice slip events recorded on the fault plane of the Andrés Landslide, El Hierro, Canary Islands. *Tectonophysics* 776, 228317. DOI: org/10.1016/j.tecto.2019.228317
- Blahůt J., Balek J., Eliaš M., Meletlidis S. (2020). 3D Dilatometer Time-Series Analysis for a Better Understanding of the Dynamics of a Giant Slow-Moving Landslide. *Applied Sciences* 10(16), 5469, 1–16. DOI: org/10.3390/app10165469
- Blahůt J., Olejár F., Rott J., Petružálek M. (2020). Current stability modelling of an incipient San Andrés giant landslide on El Hierro, Canaries, Spain – first attempt using limited input data. *Acta Geodynamica et Geomaterialia* 17, 1(197), 89–99. DOI: org/10.13168/AGG.2020.0006
- Ambrosino, F., Thinová, L., Briestenský, M. et al. (2020). Detecting time series anomalies using hybrid methods applied to Radon signals recorded in caves for possible correlation with earthquakes. *Acta Geodaetica et Geophysica* 55, 405–420. DOI: org/10.1007/s40328-020-00298-1
- Blahůt J., Quan Luna B. (2020). Tsunami from the San Andrés Landslide on El Hierro, Canary Islands: first attempt using simple scenario. *In*: Sassa K., Mikos M., Sassa S. (Eds.), Understanding and Reducing Landslide Disaster Risk, Volume 1, Sendai Partnerships and Kyoto Landslide Commitment, 8 p.
- Racek O., Blahůt J., Hartvich F. (2020). Monitoring of thermoelastic wave within a

rock mass coupling information from IR camera and crack meters: a 24-hour experiment on “Branická skála” Rock in Prague, Czechia. *In*: Casagli N.,Tofani V., Sassa K., Bobrowsky P., Takara K. (Eds.), Understanding and Reducing Landslide Disaster Risk, Volume 3, Sendai Partnerships and Kyoto Landslide Commitment, 7 p.

- Vilímek V., Klimeš J., Stemberk J., Burda J., Kycl P., Blahůt J. (2020). Complex geomorphological and engineering geological research of landslides with adverse societal impacts. *In*: Sassa K., Mikos M., Sassa S. (Eds.), Understanding and Reducing Landslide Disaster Risk, Volume 1, Sendai Partnerships and Kyoto Landslide Commitment, 6 p.
- Slavík M., Bruthans J., Weiss T., Schweigstillová J. (2020). Measurements and calculations of seasonal evaporation rate from bare sandstone surface: Implications for rock weathering. *Earth Surface Processes and Landforms* 45, Issue 12, 2965–2981. DOI: org/10.1002/esp.4943

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The Department of Neotectonics and Thermochronology in 2020 principally addressed paleo-stress conditions in the Bohemian Massif and research into the Železná Hora and Lusatian faults. In cooperation with other geoscience institutions, the department also participated in the research of permafrost, slope deformations and the structural-tectonic development of sandstone reliefs in the Czech Republic and Poland. Further, the results obtained in previous years via a study of the San Jacinto fault located southeast of Anza, California, USA were assessed and published.

The department is involved in international research via the use of the following monitoring networks:

- Subject of monitoring: slope deformations

Name of the monitoring network: SlopeNet
Operator: IRSM
Monitoring enables active involvement in research with co-responsibility for the geophysical and geotechnical monitoring of slope deformations.

- Subject of monitoring: tectonic structures

Name of the monitoring network: Network EU TecNet
Operator: IRSM
Monitoring allows for connection to the wider EU network; the taking of meter readings and the provision of service work.

Outputs:
The determination of the physical characteristics of the subsurface zone along the San Jacinto fault (California, USA) and the analysis of the velocity of seismic waves in the shallow layers of the tectonic fault zone.

Summary: the determination of the structural characteristics of the upper 100 metres of the San Jacinto fault zone (southeast of Anza, California, USA) applying the combined analysis of geological, topographic, seismic and resistance data. The study presents the results of geological, topographic, seismic and resistance surveys performed along the Clark branch in the trifurcation zone of the fault. The combined

interpretation of the data obtained allowed for the more accurate characterisation of the shallow (i.e. less than 100 m) part of the fault zone at this structurally complex site. The research revealed a 20%–37% degree of variability in the peak ground velocity (PGV) from local earthquakes across the studied area. The upper limit of this range is related to unconsolidated subsurface sediments and the north-eastern disturbed gneisses. The study was conducted via extensive international cooperation (University of California, San Diego; School of Earth and Space Exploration, Arizona State University; NASA Jet Propulsion Laboratory, California; University of Southern California, Los Angeles).

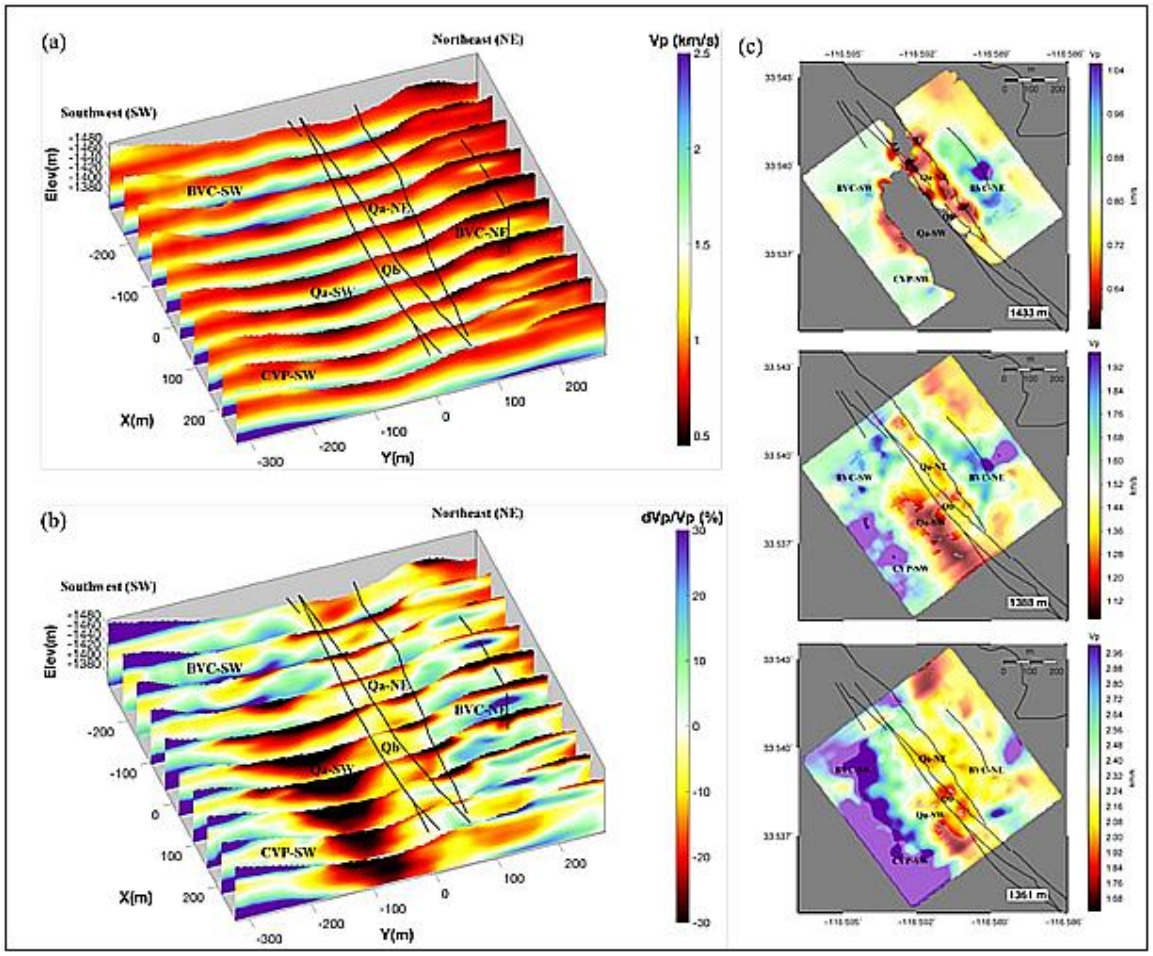

Illustration: Results of the inversion of the V_P seismic velocities. (a) Absolute V_P velocities for 10 sections along the fault, (b) the V_P model (a) relative to the applied 1-D initial model, (c) V_P sections at 1433, 1388 and 1361 m above sea level (at depths of approximately 3.5 and 70 m below the surface).

Publication:
Share P.-E., Tábořík P., Štěpančíková P., Stemberk J. jr., Rockwell T.K., Wade A., Arrowsmith J.R., Donnellan A., Vernon F.L., Ben-Zion Y. (2020). Characterizing the uppermost 100 m structure of the San Jacinto fault zone southeast of Anza, California, through joint analysis of geological, topographic, seismic and resistivity data. *Geophysical Journal International* 222(2), 781–794. DOI: 10.1093/gji/ggaa204.

- The hypogenetic versus the epigenetic origin of deep underwater caves applying the example of the Hranice abyss (Czech Republic) - the world's deepest freshwater cave.

Summary: A range of geophysical measurements were taken so as to determine the extent and form of the Hranice abyss. The geophysical results suggested that the depth of the abyss is up to ~ 1 km. Further, karst structures were identified, including a buried tower-like karst formation. The new geophysical results, interpreted in the context of the local tectonic development and the morphology of karst structures, indicate the epigenetic origin of the formation of the abyss despite the traditionally-accepted theory of its hypogenetic origin, which has implications in terms of the local and regional development of karsts in areas that feature deep karst systems.

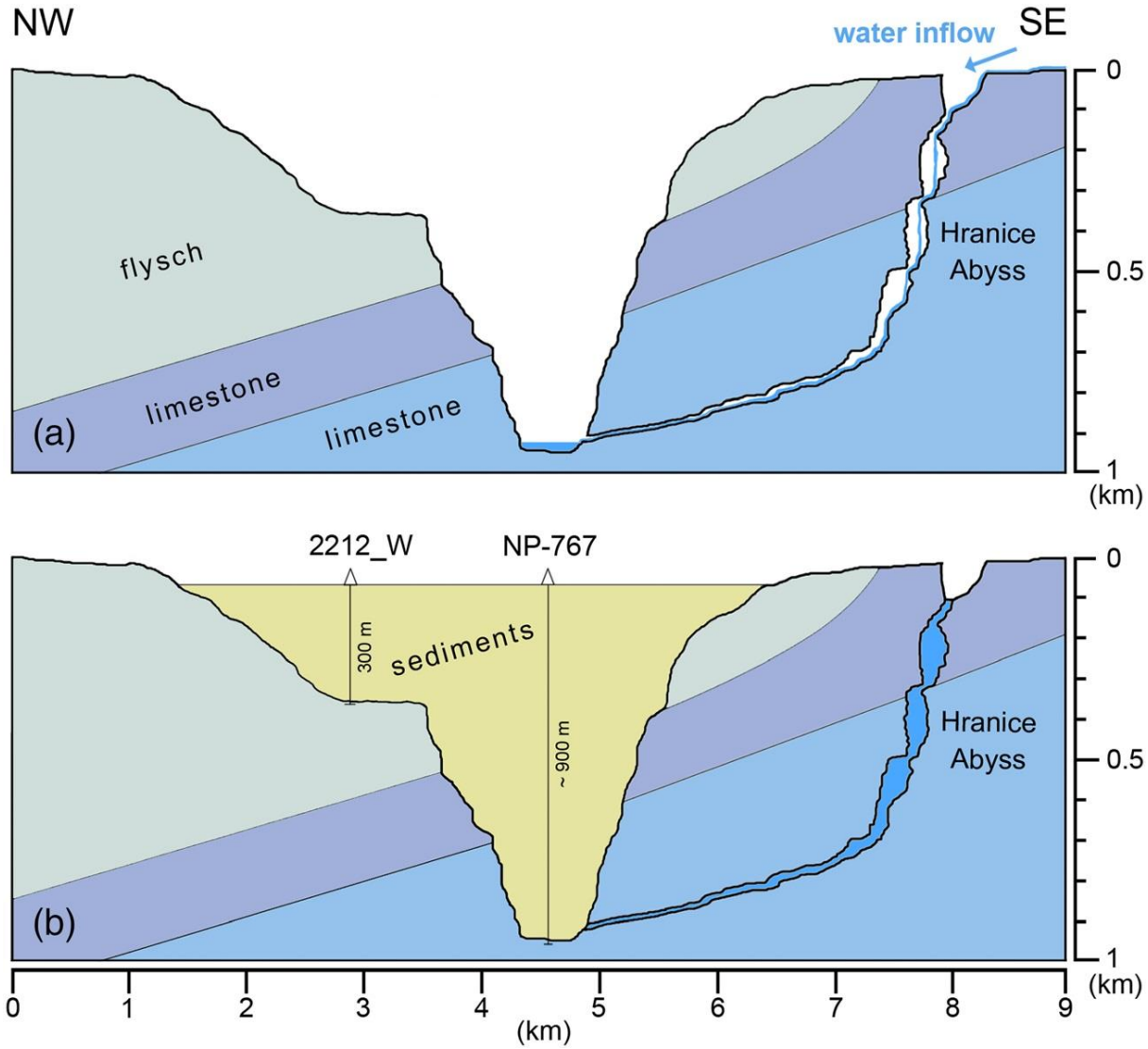

Illustration: Conceptual geological section across the Hranice abyss and the Carpathian foredeep. Image (a) depicts the situation during the early Langhian (Neogene/Miocene) at which time the Carpathian foredeep was opened and the Hranice abyss was formed; image (b) shows the current situation.

Publication:
Klanica R., Kadlec J., Tábořík P., Mrlina J., Valenta J., Kováčiková S., Hill G.J. (2020). Hypogenic versus epigenic origin of deep underwater caves illustrated on the

Hranice Abyss (Czech Republic) - the world's deepest freshwater cave. *Journal of Geophysical Research: Earth Surface* 125(9), e2020JF005663. DOI: org/10.1029/2020JF005663

- Old but still active: the over 18,000-year history of rock slope failures that affected a flysch anticline.

Summary: the research focused on rock landslides that affected a flysch anticline. The structural-geological research, kinematic analysis and the results of shallow geophysical exploration revealed the structural-geological predisposition of the rock landslides with the presence of topple failures and lateral disintegration. Based on beryllium (^{10}Be) dating, the long-term history of the slope failures was reconstructed, revealing the maximum occurrence of these phenomena 18 and 12 thousand years ago. Dendro-geomorphological analysis revealed significant indications of annual slope movements over the last 150 years. These findings suggest the progressive development of slope failures in certain parts of the rock landslide.

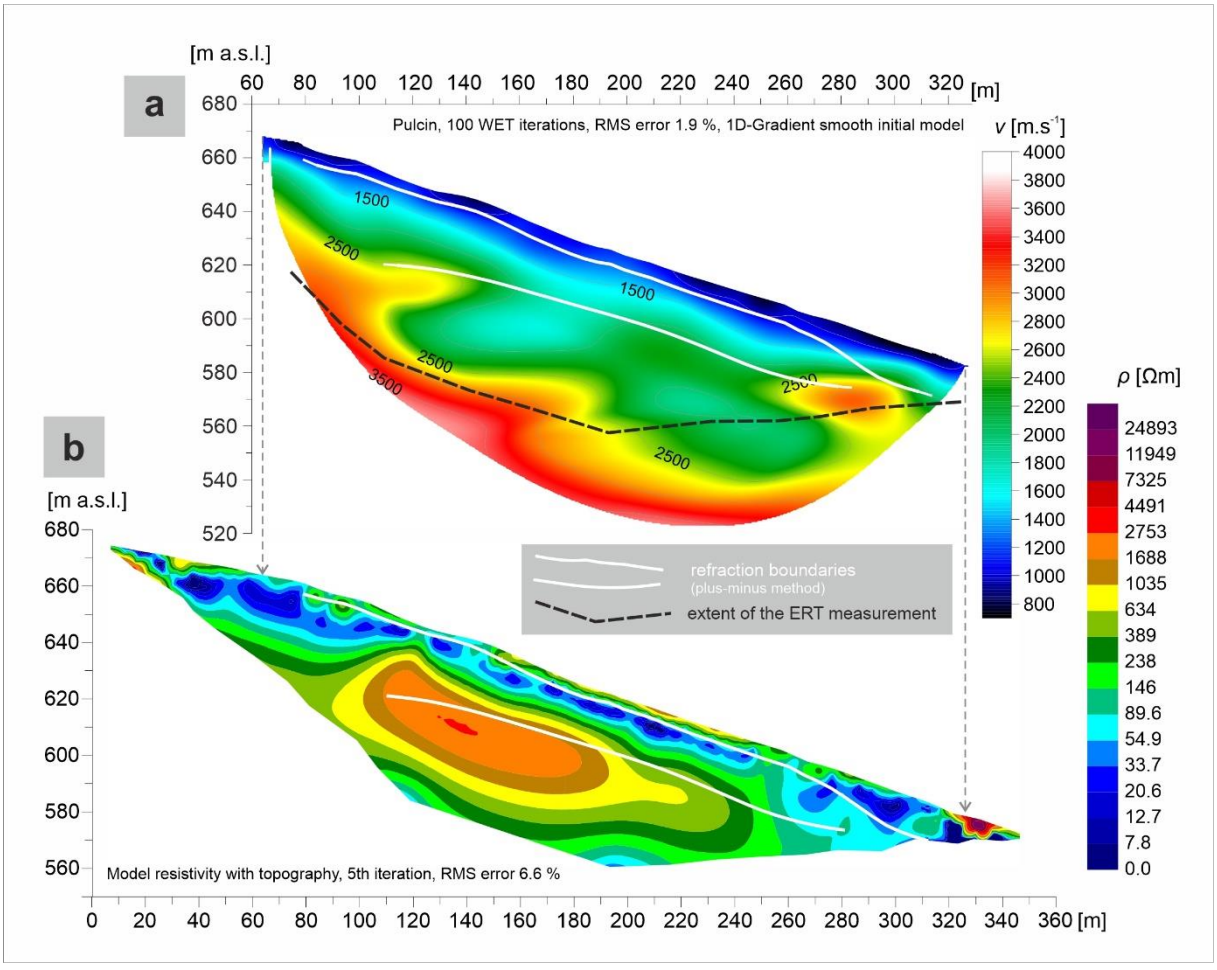

Illustration: Geophysical survey of a "lobed" accumulation on the northern slope. a) Shallow refractive seismics depicted as an inverse tomographic seismic velocity model. (b) Multi-electrode resistance measurements processed via electrical resistance tomography (inverse model). The white solid line shows the refractive ("break") interface derived by means of the "t0 method" (the analysis of seismic signal arrival times).

Publication:
Březný M., Pánek T., Braucher R., Šilhán K., Chalupa V., Lenart J., Tábořík P., Aster Team (2020): Old but still active: >18 ka history of rock slope failures affecting a flysch anticline. *Landslides* 18 (v tisku). DOI: 10.1007/s10346-020-01483-7

Other outputs:

- Adamovič J., Coubal M. (2020). Tectonic structure. *In*: Vařilová Z. (Ed.), Geology of Bohemian Switzerland, pp. 109–131. Bohemian Switzerland National Park Authority, ISBN 978-80-87620-20-5.
https://www.databazeknih.cz/knihy/geologie-ceskosaskeho-svycarska-443983

- Sana H. (2020). Synthetic ground motions of the 2005 Kashmir M7.6 earthquake at the bedrock and at surface using stochastic dynamic finite fault modelling with a dynamic corner, Chapter 1. *In*: Samui P., Dixon B., Bui D.T. (Eds.), Basics of Computational Geophysics, 1st Edition. Elsevier, ISBN 978-0-12-820513-6.
https://www.elsevier.com/books/basics-of-computational-geophysics/samui/978-0-12-820513-6

- Sana H. (2020). Liquefaction as a seismic hazard: scales, examples and analysis, Chapter 10. *In*: Samui P., Dixon B., Bui D.T. (Eds.), Basics of Computational Geophysics, 1st Edition. Elsevier, ISBN: 978-0-12-820513-6.
https://www.elsevier.com/books/basics-of-computational-geophysics/samui/978-0-12-820513-6

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The Department of Seismotectonics continued the ongoing study of natural seismic phenomena associated with the dynamics and tectonic evolution of structures in the earth's crust (especially in the upper part of the crust), seismic phenomena induced by anthropogenic activity and the development of methods for the assessment of geophysical measurements. Moreover, the development of monitoring devices and methodologies for the research of seismic activity continued during the year as did the assessment of seismic hazards affecting nuclear power plants.

The department is involved in international research via the following monitoring networks:

- Subject of monitoring: earthquakes in the Czech Republic and worldwide

Name of the monitoring network: Czech Regional Seismic network
Operators: Academy of Sciences of the Czech Republic (AV CR): Institute of Geophysics (AV CR), the IRSM, Institute of Geonics (AV CR); Institute of Earth Physics, Masaryk university; Charles University Faculty of Mathematics and Physics.
The network serves as the basic scientific infrastructure for earthquake research.

- Subject of monitoring: earthquakes in Iceland

Name of the monitoring network: REYKJANET
Operators: Institute of Geophysics (AV CR) and the IRSM.
Monitoring allows for the detailed scientific research of seismically-active areas.

- Subject of monitoring: earthquakes in the Lesser Carpathians

Name of the monitoring network: MKNET
Operators: the IRSM; Institute of Geophysics, Bratislava + Progseis s.r.o.
Monitoring allows for the continuous recording and assessment of data obtained from seismically-active areas.

- Subject of monitoring: earthquake research in Central and Eastern Europe

Name of the monitoring network: Central Eastern Europe Earthquake Research Network
Operators: 15 institutions in Central and Eastern Europe
Involvement in monitoring activities provides for the exchange of seismic data.

Outputs:

- The amplifying effects of a thin shallow stiff layer on Love waves based on the multi-component analysis of surface waves.

Summary: The multi-component surface wave analysis revealed that thin shallow stiff layers excite the higher modes of Love waves in a very specific way, and that the highest velocity of these higher modes is influenced by the velocity of transverse waves in the deeper layers. This means that if a stiff surface layer is present - and this is quite common in urban areas - Love waves have the potential to provide a useful tool for the prompt estimation of the velocity of shear waves in deeper layers.

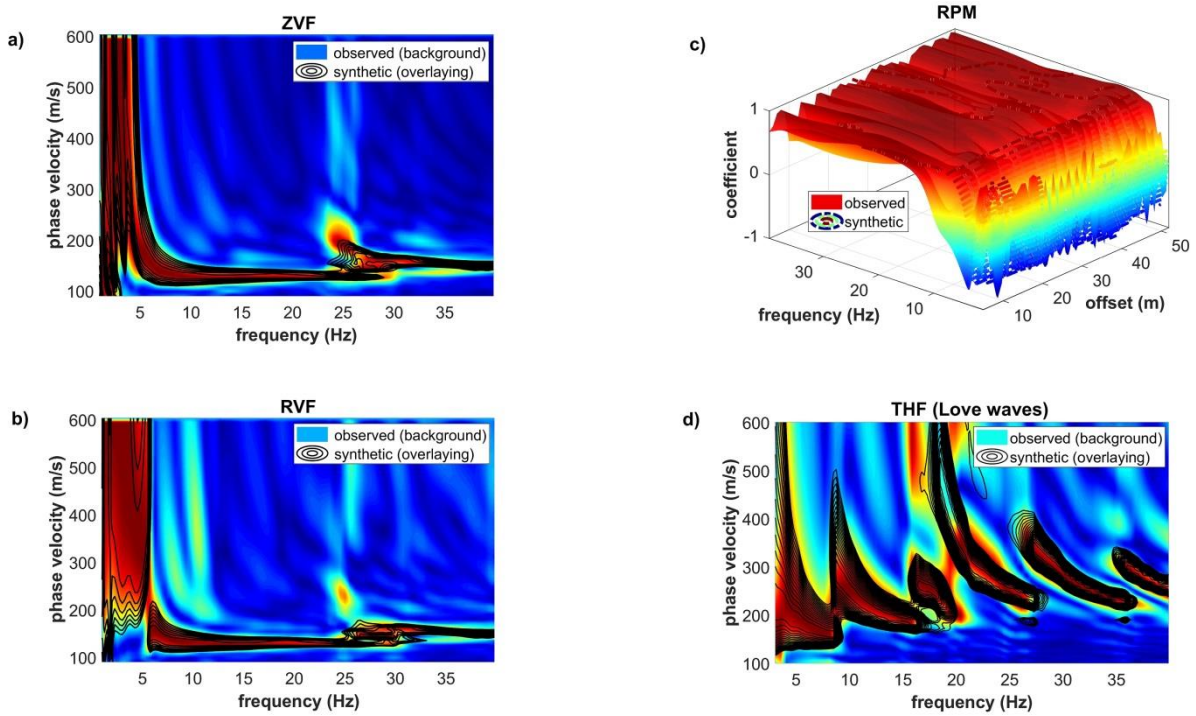

Illustration: Phase velocity spectra for components Z, R and T (a), (b), (d), respectively. Love waves exhibit typical excitation in the higher mode together with the RPM (Rayleigh-wave-Particle Motion) frequency shift (c).

Publication:
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, 1–13. DOI: org/10.1038/s41598-020-66070-1

- The comparative measurement of local seismic rotations by means of three independent methods.

Summary: an active comparative experiment was performed aimed at measuring the speed of seismic rotational movements applying three different methods: the Rotafon 6C six-component sensor system, the commercial R-1 rotary sensor purchased from Eentec Ltd, and a group of twelve standard velocimeters in a rectangular network. The seismic source comprised quarry blasting. A comparison was made with the respective acceleration components according to the theoretical relationships between rotation and acceleration. The Rotafon measurements were found to be best suited for such relationships.

Publication:
Brokešová J., Málek J. (2020). Comparative Measurements of Local Seismic Rotations by Three Independent Methods. Sensors 20(19), 5679, 1–23.
DOI: 10.3390/S20195679

- The analysis of microseismicity and the reactivated fault size for the assessment of potential phenomena induced by the injection of CO_2 into the Illinois lowlands.

Summary: only recently has the importance been acknowledged of the passive monitoring of induced seismicity prior to and during the storage of CO_2 in the subsoil. Active and passive seismic data were integrated so as to create an updated interpretation of the subsurface structure at the site. The observed microseismicity was found to be caused by clusters along smaller faults that were not previously identified via the reflex seismic data. Only following the re-processing of the reflex seismic data was it possible to verify these faults and so determine the seismic hazard risk. The calculations performed are important from the point of view of being able to provide warning of potential larger-scale earthquakes and other seismic phenomena.

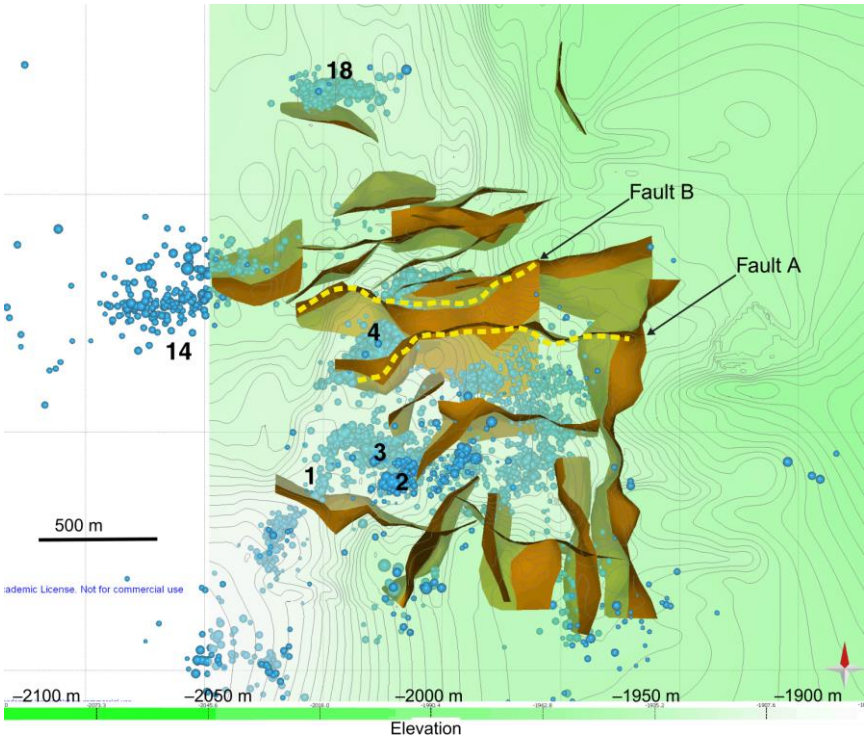

Illustration: Colour-coded map of the microseismicity and the A and B interpreted faults.

Publication:
Williams-Stroud S., Bauer R., Leetaru H., Oye V., Staněk F., Greenberg S., Langet N. (2020). Analysis of Microseismicity and Reactivated Fault Size to Assess the Potential for Felt Events by CO_2 Injection in the Illinois Basin. *Bulletin of the Seismological Society of America* 110 (5), 2188–2204.
DOI: org/10.1785/0120200112

Further outputs:

- Li L., Tan J., Schwarz B., Staněk F., Poiata N., Shi P., Diekmann L., Eisner L., Gajewski D. (2020). Recent Advances and Challenges of Waveform-Based Seismic Location Methods at Multiple Scales. *Reviews of Geophysics* 58, Issue 1, e2019RG000667. DOI: org/10.1029/2019RG000667

- Dal Moro G. (2020). On the identification of industrial components in the Horizontal-to-Vertical Spectral Ratio (HVSR) from microtremors. *Pure and Applied Geophysics*177, 3831–3849. DOI: org/10.1007/s00024-020-02424-0

- Patent no. CZ 308559 (2020)
Málek J.: A container for the deep disposal of spent nuclear fuel and a method for the deep disposal of spent nuclear via the use of the container. Patent holder: IRSM, Prague 8.

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The Department of Geochemistry focused during the year on the research of the composition, texture and properties of rocks and rock-derived materials via surface chemistry, geochemistry and petrology methods with respect particularly to the mineral composition of rocks and materials, the formation processes related to, and the accumulation of, organic matter in rocks, and the characterisation of both the various biological sources involved and the wider paleo-environment.
Further, imperfect combustion products were analysed and the migration of toxic elements investigated in connection with environmental contamination issues. In addition, the sorption of carbon dioxide and methane in porous natural and artificial materials was studied dependent on the properties of the materials considered, and new micro-mesoporous carbonaceous materials were developed that provide for the adsorption of CO_2.

Following on from previous research, an investigation was conducted of the hydrothermal uranium mineralisation present in the amphibolic-biotite granodiorites of the Blato suite via the study of small uranium deposits at Nahošín and Mečichov located along the south-western edge of the Central Bohemian plutonic complex. The uranium mineralisation consisting of coffinite and, occasionally, uraninite and thorite was found to be accompanied by the intensive hematitisation, albitisation, chlorination and carbonation of the original granodiorites. The alterations were accompanied by accumulations of the elements U, Ca, Na, K, Y and Zr and lower concentrations of Si, Ba and Sr.

Output:

- The influence of the properties of Czech Silurian shales on the sorption capacity of methane and carbon dioxide. An experimental study of carbon dioxide and methane sorption dependent on the composition and porosity of Barrandian Silurian shales.

Summary: an experimental study of the sorption capacities of CO_2 and CH_4 and their dependence on the composition and porosity of Czech Silurian shales from three areas of the Barrandian was conducted applying the mercury high-pressure gas adsorption method. The total sorption capacities were determined for CO_2 (0.118 - 0.244 mmol/g) and for CH_4 (0.050 - 0.088 mmol/g). It was observed that the sorption of CO_2 is influenced by the content of quartz in the shale, while the sorption of CH_4 depends primarily on the presence of carbon and clay minerals. The research provided for the compilation of globally unique pore size distribution curves.

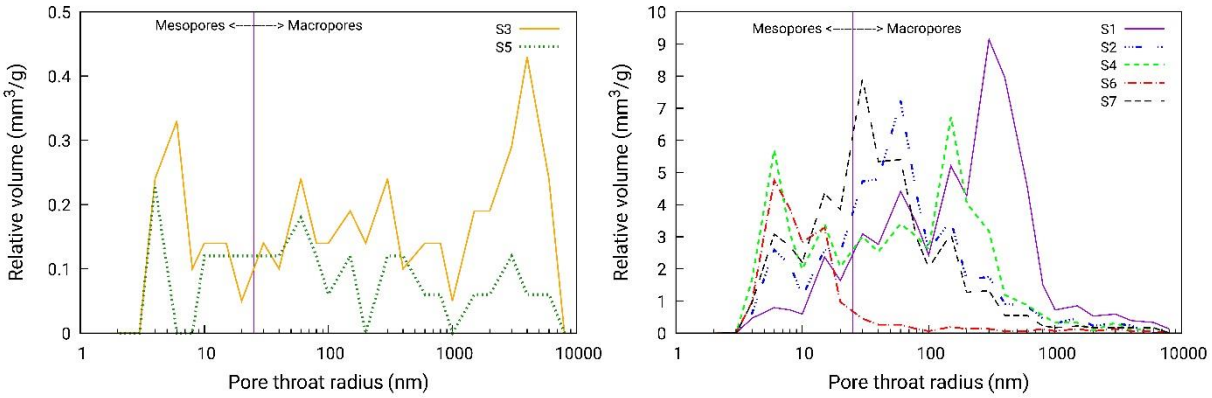


Illustration: The unique pore size distribution curves for the various shale samples subjected to mercury porosimetry analysis highlight the differences in the pore content. The graphs show the distribution of the mesopores and macropores for the shale samples with both a predominant content of pores in the meso and macro regions (right) and with a dominant content of micropores (left).

Publication:
Řimnáčová D., Weishauptová Z., Přibyl O., Sýkorová I., René M. (2020). The effect of the properties of shales on the CH_4 and CO_2 sorption capacity of Czech Silurian shales. *Journal of Natural Gas Science and Engineering* 80, 103377. ISSN 1875-5100, DOI: 10.1016/j.jngse.2020.103377

Further outputs:

- Havelcová M., Machovič V., René M., Sýkorová I., Lapčák L., Špaldoňová A. (2020). Geochemistry of shear zone-hosted uranium mineralisation at the Zadní Chodov uranium deposit (Bohemian Massif). *Ore Geology Reviews* 120, 103428. DOI: org/10.1016/j.oregeorev.2020.103428

- Mansour A., Geršlová E., Sýkorová I., Vöröš D. (2020). Hydrocarbon potential and depositional paleoenvironment of a Middle Jurassic succession in the Falak-21 well, Shushan Basin, Egypt: Integrated palynological, geochemical and organic petrographic approach. *International Journal of Coal Geology* 219, 103374. DOI: org/10.1016/j.coal.2019.103374

- Misz-Kennan M., Kus J., Flores D., Avila C., Büçkün Z., Choudhury N., Christanis K., Joubert J.P., Kalaitzidis S., Karayigit A.I., Malecha M., Marques M., Martizzi P., O'Keefe J.M.K., Pickell W., Predeanu G., Pusz S., Ribeiro J., Rodrigues S., Singh A.K., Suárez-Ruiz I., Sýkorová I., Wagner N.J., Životić D. (2020). Development of a petrographic classification system for organic particles affected by self-heating in coal waste. (An ICCP Classification System, Self-heating Working Group – Commission III). *International Journal of Coal Geology* 220, 103411.
DOI: org/10.1016/j.coal.2020.103411

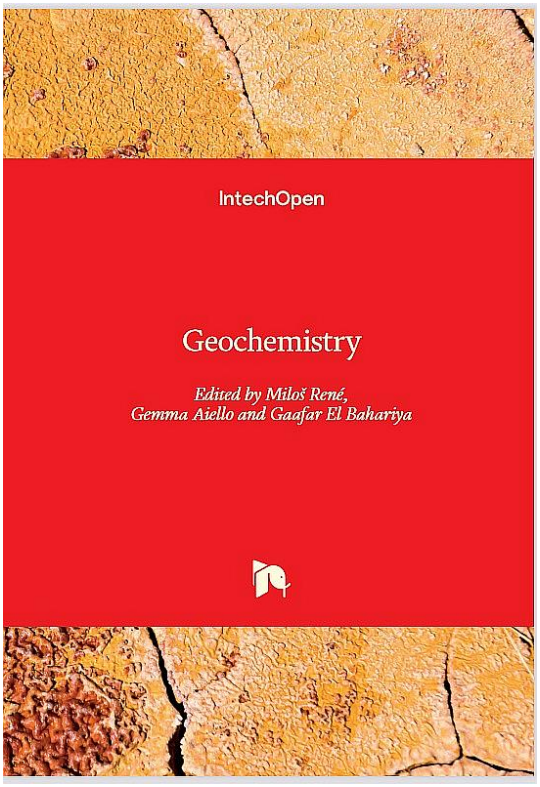
- Havelcová M., Machovič V., Novák F., Lapčák L., Mizera J., Hendrych J. (2020). Chemical characterization of mountain forest soils: impact of long-term atmospheric deposition loadings (Czech–Polish–German border region). *Environmental Science and Pollution Research* 27, 20344–20357. DOI: org/10.1007/s11356-020-08558-x

- Kříbek B., Míková J., Knésl I., Mihajlevič M., Sýkorová I. (2020). Uptake of trace elements and isotope fractionation of Cu and Zn by birch (*Betula pendula*) growing on mineralised coal waste pile. *Applied Geochemistry* 122, 104741.
DOI: org/10.1016/j.apgeochem.2020.104741

- H.G.T. Nguyen, C.M. Sims, B. Toman, J. Horn, R.D. van Zee, M. Thommes, R. Ahmad, J.F.M. Denayer, G. V. Baron, E. Napolitano, M. Bielewski, E. Mangano, S. Brandani, D.P. Broom, M.J. Benham, A. Dailly, F. Dreisbach, S. Edubilli, S. Gumma, J. Möllmer, M. Lange, M. Tian, T.J. Mays, T. Shigeoka, S. Yamakita, M. Hakuman, Y. Nakada, K. Nakai, J. Hwang, R. Pini, H. Jiang, A.D. Ebner, M.A. Nicholson, J.A. Ritter, J. Farrando-Pérez, C. Cuadrado-Collados, J. Silvestre-Albero, C. Tampaxis, T. Steriotis, D. Řimnáčová, M. Švábová, M. Vorokhta, H. Wang, E. Bovens, N. Heymans, G. De Weireld (2020). A reference high-pressure CH_4 adsorption isotherm for zeolite Y: results of an interlaboratory study. *Adsorption* 26, 1253–1266.
DOI: org/10.1007/s10450-020-00253-0

- Jirman P., Geršlová E., Bubík M., Medvecká L. (2020). Source rock potential of the Menilite Formation in the Czech sector of the Subsilesian Unit. *Geologica Carphatica* 71, 5, 402–417. DOI: org/10.31577/GeolCarp.71.5.2

- René M. (2020). Geochemistry of granitic rocks of the Moldanubian batholith (Central European Variscides). *In*: Geochemistry. René Miloš, Gemma Aiello and Gaafar El Bahariya (Eds.), IntechOpen, London, 1–18.
DOI: 10.5772/intechopen.93189.



- Patent no. CZ 308278 (2020)
Marek Šváb, Martina Švábová: Method for the regeneration and/or reactivation of activated carbon in a reaction stage furnace and the reaction stage furnace required for this method. Patent holders: DEKONTA, a.s., Dřetovice; IRSM, Prague 8.

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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 related to collagen replacements and patches for use in vascular surgery. Since the mechanical properties of collagen hydrogels that are used in such applications are not ideal, research during the year focused on the improvement of their properties via the approach to preparation, reinforcement using collagen fibres and the use of the activity of cells, all of which are able to transform collagen hydrogels into structurally and mechanically suitable materials under static or dynamic conditions. The second research area concerned resorbable arterial bandages based on a composite material composed of a synthetic PCL/PLA copolymer nanofibre reinforcement combined with a collagen matrix for the purposes of the reduction of the flow of blood through the arterial bed and the protection of the arterial wall from pathological deformity and rupture. The department further focused on the description of the delamination properties of the human aorta. This concerns the research of materials in terms of the physico-chemical and mechanical properties of biological tissues aimed at addressing issues related to the spread of cracks in arteries, which occur during arterial dissection and rupture and which may be life-threatening. Other activities included the study of the physico-chemical parameters of bone bioapatite isolated from bones obtained from donors.

The results of the characterisation of the isolates will be used in a proposal for the use of materials that otherwise remain unused in bone banks following the preparation of bone grafts.

A further research area related to high-temperature composites, concerning which the department focused on the development of hybrid composites with a partially pyrolysed polysiloxane matrix reinforced with silicate fibres. Particular attention was devoted during the year to the study of structural changes resulting from the heating of basalt fibres above 700°C. The research also included the laboratory preparation of such composites, in which textile materials with various weaves were used for reinforcement purposes. The resulting material was subjected to mechanical testing and testing at elevated temperatures, including fire testing. Other activities in this area focused on the study of the rheological properties of pre-ceramic polymers measured *in situ* when subjected to pyrolysis.

Outputs:

- The fracture resistance of partially pyrolysed polysiloxane pre-ceramic polymer composites reinforced with unidirectional basalt fibres.

Summary: two types of composite materials were studied based on continuous unidirectional basalt fibres and a matrix prepared based on a polysiloxane pre-ceramic resin partially pyrolysed at 650°C and a matrix cured from polysiloxane alone or with an epoxy resin. A direct comparison was conducted for the first time of the resulting partially pyrolysed composites with commonly-used polymer composites at elevated temperatures.

Publication:
Chlup Z., Černý M., Kácha P., Hadraba H., Strachota A. (2020). Fracture resistance of partially pyrolysed polysiloxane preceramic polymer matrix composites reinforced by unidirectional basalt fibres. *Journal of the European Ceramic Society* 40, 4879–4885. DOI: 10.1016/j.jeurceramsoc.2020.01.047

- The surface treatment of acetabular wells with the direct deposition of a composite nano-structured layer applying a high electrostatic field.

Summary: a composite collagen-calcium phosphate nanofibre layer was applied to the irregular surfaces of three-dimensional titanium acetabular wells using a specially-developed electrospinning system designed so as to ensure process stability and the homogeneity of the resulting layers and the nanofibre morphology thereof. The resulting nanofibre layers and the application method represent a promising approach to the surface modification of metal implants.

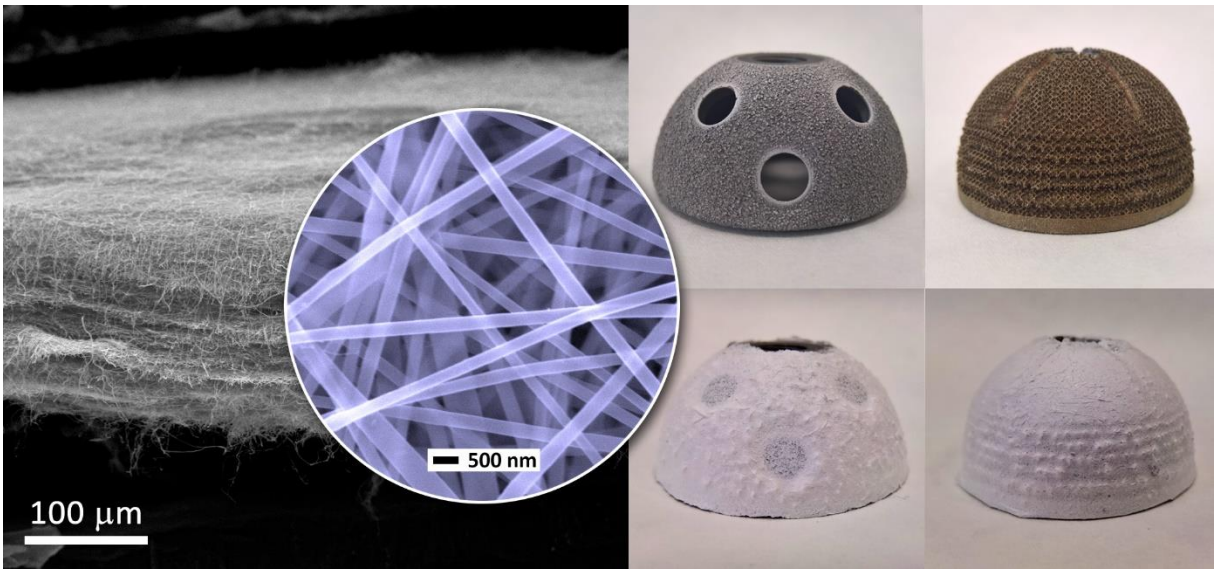

Illustration: demonstration of the direct application of collagen-calcium phosphate nanolayers to the surfaces of orthopaedic implants.

Publication:
Pokorný M., Suchý T., Kotziánová A., Klemeš J., Denk F., Šupová M., Sucharda Z., Sedláček R., Horný L., Králík V., Velebný V., Čejka Z. (2020). Surface Treatment of Acetabular Cups With a Direct Deposition of a Composite Nanostructured Layer Using a High Electrostatic Field. *Molecules* 25(5) (2020) 1173. DOI:10.3390/molecules25051173

Further outputs:

- Tesař K., Balík K. (2020). Nucleation of corrosion products on H_2 bubbles: A problem for biodegradable magnesium implants? *Materials Today* 35, 195–196. DOI: 10.1016/j.mattod.2020.04.001

- Tesař K., Balík K., Sucharda Z., Jäger A. (2020). Direct extrusion of thin Mg wires for biomedical applications. *Transactions of Nonferrous Metals Society of China* 30(2), 373–381. DOI: 10.1016/S1003-6326(20)65219-0

- Šmrhová T, Junková P, Kučková Š, Suchý T, Šupová M. (2020). Peptide mass mapping in bioapatites isolated from animal bones. *Journal of Materials Science: Materials in Medicine* 31, 32. DOI:10.1007/s10856-020-06371-z

- Hartinger J.M., Lukáč P., Mlček M., Popková M., Suchý T., Šupová M., Chlup H., Horný L., Závora J., Adámkova V., Slanař O., Kozlík P., Molnarova K., Honsová E., Lambert L., Grus T. (2020). Rifampin-Releasing Triple-Layer Cross-Linked Fresh Water Fish Collagen Sponges as Wound Dressings. *BioMed Research International*, 3841861. DOI: 10.1155/2020/3841861

- Hartinger J.M., Lukáč P., Mitáš P., Mlček M., Popková M., Suchý T., Šupová M., Závora J, Adámková V., Benáková H., Slanař O., Šíma M., Bartoš M., Chlup H., Grus T. (2020). Vancomycin releasing cross-linked collagen sponges as wound dressings. *Bosnian Journal of Basic Medical Sciences*, 3841861. DOI: 10.1155/2020/3841861

- Černý M, Chlup Z, Strachota A, Halasová M, Schweigstillová J, Kácha P, Svítilová J. (2020). Potential of glass, basalt or carbon fibres for reinforcement of partially pyrolysed composites with improved temperature and fire resistance. *Ceramics–*

Silikáty 64(2), 115–124. DOI: 10.13168/cs.2019.0056

- European patent no. EP3311854 (2020)
Suchý T., Šupová M., Denk F., Rýglová Š., Žaloudková M., Sucharda Z., Ballay R., Horný L., Čejka Z., Pokorný M., Knotková K., Velebný V.: A nanocomposite layer on the basis of collagen nanofibers, and a method of preparation thereof.
http://hdl.handle.net/11104/0311567
https://data.epo.org/gpi/EP3311854A1

- Utility model no. CZ 34045 (2020)
Grus T., Suchý T., Šupová M., Chlup H., Horný L.: A degradable highly-porous collagen foam for the controlled release of active substances (2020). Owners: the General University Hospital in Prague, Prague 2; the IRSM, Prague 8; the Czech Technical University in Prague, Prague 6.

- Utility model no. CZ 33755 (2020)
Grus T., Suchý T., Šupová M., Chlup H.: A sandwich collagen foam with a slightly-porous core and highly-porous edge layers for the controlled release of active substances. Owners: the General University Hospital in Prague, Prague 2; the IRSM, Prague 8; the Czech Technical University in Prague, Prague 6.

- Utility model no. CZ 33802 (2020)
Grus T., Suchý T., Šupová M., Chlup H.: A nanostructured highly-porous composite collagen foam for the controlled release of active substances. Owners: the General University Hospital in Prague, Prague 2; the IRSM, Prague 8; the Czech Technical University in Prague, Prague 6.

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The Department of the Structure and Properties of Materials focused during the year on the modelling of glass smelting processes in the fields of the research of glass and glass technologies, the ongoing development of new smelting facilities and the observation of changes in the inhomogeneities in glass melts at high temperatures. The experimental research and modelling of radioactive waste vitrification processes and the preparation of infrared transmissive glass (chalcogenide and heavy metal oxide glass) including its characterisation continued during the year.

A study was conducted on the use of various types of waste suitable as additives and fillers in the production of new composites based on geopolymers. The incorporation of such waste into a geopolymer matrix exerts a positive effect on the reduction of environmental impacts and the overall improvement of the environment; the resulting materials have a wide range of applications. The study included the long-term investigation and description of the phase transformations of fluid ash obtained from coal combustion incorporated into a geopolymer matrix with quartz sand.

As part of a TA CR project, cooperation continued with the University of Chemical Technology, the Institute of Chemical Processes of the AS CR, and the industrial company TARPO s.r.o. concerning the conversion of stabilised sewage sludge, the output of which was the granting of a patent for a device and methodology for the energy use of sewage sludge.

Furthermore, as part of the “Efficient energy conversion and storage” programme of the AV21 Strategy, a joint project conducted with the Institute of Chemical Processes of the AS CR and the Institute of Plasma Physics of the AS CR

focused on novel and clean approaches to plastic waste processing, and sub-project 2-06 “The potential for the cracking of waste polyethylene into a mixture of hydrocarbons: the technological verification of a heat treatment method” (TA CR project TP01010055, GAMA 2 programme: Geophysics, geotechnics, geomaterials, geothermal energy for practical use (4GEO)).

Cooperation commenced with the Institute of Theoretical and Applied Mechanics of the AS CR as part of the AV21 Strategy programme “The city as a laboratory of change; buildings, cultural heritage and an environment for a safe and fulfilling life”. Initial discussions and a workshop were held with restorers, architects and sculptors.

Outputs:

- Phase transformations in solids based on fly ash as an industrial waste product, the amount of which is constantly increasing and, due to the curing properties of which, can be used for the production of building materials.

Summary: a description of phase transformations that occurred within fluidised ash building materials over eight years from the initial to the final phase. The experiments included the fabrication of bricks from various mixtures of fly ash and silica sand. The subsequent mineralogical analysis of samples of various ages confirmed differences in the phase composition; it was determined that the content of the X-ray-amorphous parts of aluminosilicates play the major role in phase transformations in terms of the ability to transform into the form of stable feldspar.

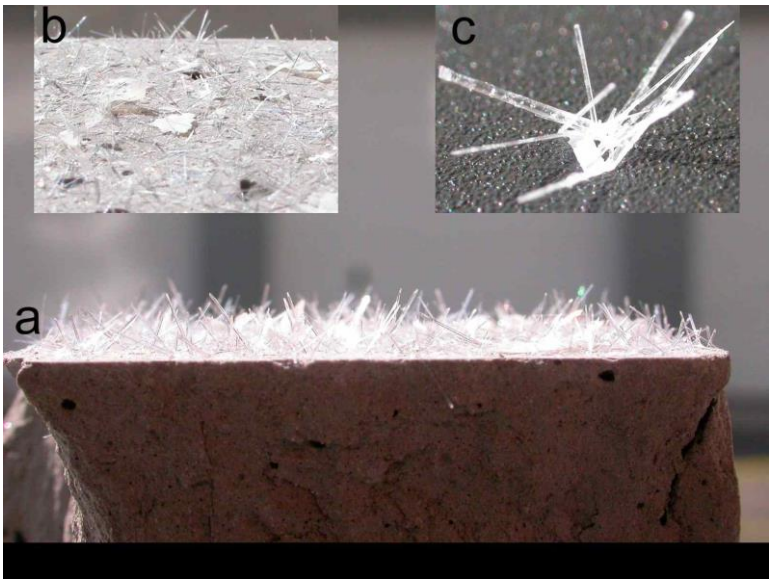

Illustration: surface of an ash sample: (a) general view of the surface of the test brick with crystal efflorescence, (b) the surface with flake crystals, (c) the surface with needle crystals.

Publication:
Perná I., Hanzlíček T., Šupová M., Novotná M. (2020). Phase Transformations in Fly Ash-Based Solids. *Minerals* 10(9), 804, 1–13.
ISSN 2075-163X, DOI: 10.3390/min10090804.

- The modelling of glass batch smelting: the influence of heat transfer and reaction kinetics

Summary: The development of mathematical models of the transfer of heat and mass in glass smelters began as early as in the 1970s, and the pace of development has accelerated thanks to advanced experimental and numerical methods and the availability of computational power. Today, virtually all newly-constructed or rebuilt smelters are optimised via mathematical modelling, the aim of which is to achieve the maximum product quality while reducing production costs and managing emissions. The last remaining obstacle is to model the conversion of glass batches to enamel. Two key aspects of the modelling of the conversion of glass batches to enamel were studied during the year, i.e. heat transfer and conversion reaction kinetics, and the current state of knowledge was revised.

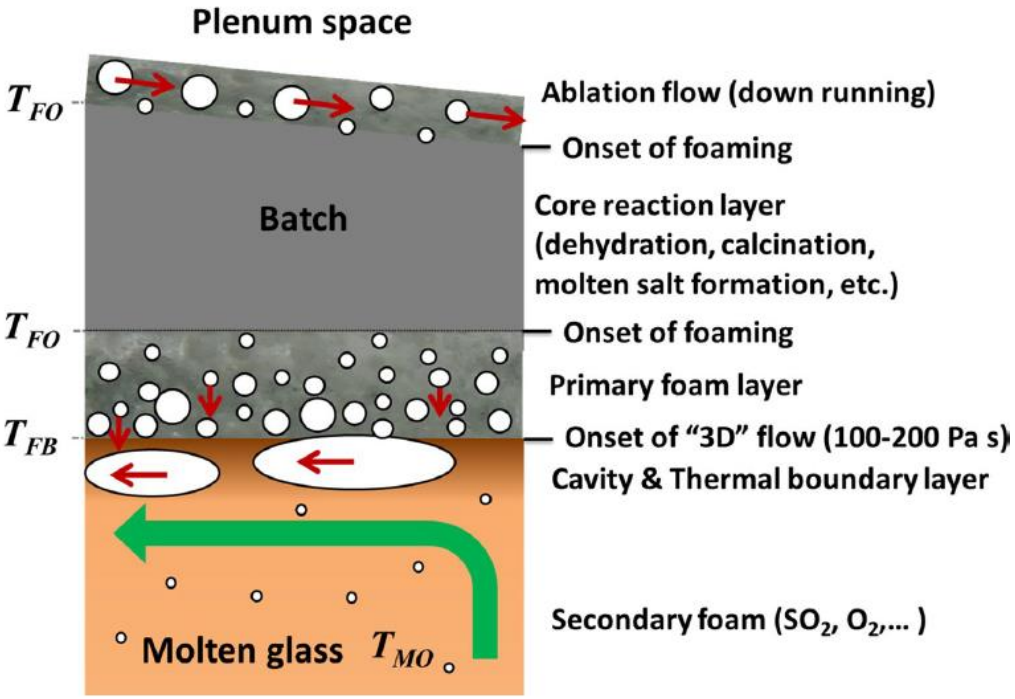

Illustration: diagram of the structure of the batch layer (T_{FO} is the foaming/smelting onset temperature, T_{FB} is the foam-batch phase interface temperature and T_{MO} is the smelter operating temperature.

Publication:

Pokorný R., Hrma P., Lee S., Kloužek J., Choudhary M.K., Kruger A.A. (2020). Modeling batch melting: Roles of heat transfer and reaction kinetics. *Journal of the American Ceramic Society* 103, 701– 718. DOI: org/10.1111/jace.16898

Further outputs:

Hujová M., Kloužek J., Cutforth, D., Lee S., Miller M., Kruger A., Hrma P., Pokorný R. (2020). Feed-to-glass conversion during low activity waste vitrification. *Ceramics International* 46, 9826–9833. DOI: 10.1016/j.ceramint.2019.12.256

Luksic S., Pokorný R., Jaime G., Hrma P., Varga T., Reno L., Buchko A., Kruger A. (2020). *In situ* characterization of foam morphology during melting of simulated waste glass using x-ray computed tomography. *Ceramics International* 46, 17176–17185. DOI: 10.1016/j.ceramint.2020.02.215

Lee S., Ferkl P., Pokorný R., Kloužek J., Hrma P., Eaton W., Kruger A. (2020). Simplified melting rate correlation for radioactive waste vitrification in electric furnaces. *Journal of the American Ceramic Society* 103, 5573–5578. DOI: 10.1111/jace.17281

Pereira L., Kloužek J., Vernerová M., Laplace A., Pigeonneau F. (2020). Experimental and Numerical Investigations of an Oxygen Single Bubble Shrinkage in a Borosilicate Glass-Forming Liquid Doped with Cerium Oxide. *Journal of the American Ceramic Society* 103, 6736–6745. DOI: 10.1111/jace.17398

Ueda N., Vernerová M., Kloužek J., Ferkl P., Hrma P., Yano T., Pokorný R. (2020). Conversion kinetics of container glass batch melting. *Journal of the American Ceramic Society* 104, 34–44. DOI: 10.1111/jace.17406

Guillen D.P., Lee S., Hrma P., Traverso J., Pokorný R., Kloužek J., Kruger A.A. (2020). Evolution of Chromium, Manganese and Iron Oxidation State during Conversion of Nuclear Waste Melter Feed to Molten Glass. *Journal of Non-Crystalline Solids* 531, 119860. DOI: 10.1016/j.jnoncrysol.2019.119860

Hanzlíček T., Perná I., Uličná K., Římal V., Štěpánková H. (2020). The Evaluation of Clay Suitability for Geopolymer Technology. *Minerals* 10, 852, 1–14. DOI:10.3390/min10100852

Perná I., Hanzlíček T., Žaloudková M. (2020). Microscopic study of the concrete / geopolymer coating interface. *Ceramics–Silikáty* 64, 68–74. DOI:10.13168/cs.2019.0050.

Abboud A.W., Guillen D.P., Pokorny R. (2020). Effect of Cold Cap Coverage and Emissivity on the Plenum Temperature in a Pilot Scale Waste Vitrification Melter. *International Journal of Applied Glass Science* 11, 357–368. DOI: 10.1111/ijag.15031

Marcial J., Pokorný R., Kloužek J., Vernerová M., Lee S., Hrma P., Kruger A. (2020). Effect of water vapor and thermal history on nuclear waste feed conversion to glass. *International Journal of Applied Glass Science* 12, 145–157. DOI: 10.1111/ijag.15803

Kolářová M., Kloužková A., Kloužek J., Schwarz J. (2020). Thermal behaviour of ,glazed ceramic bodies. *Journal of Thermal Analysis and Calorimetry* 142, 217–229. DOI: 10.1007/s10973-020-09484-3

Utility model no. CZ 33564 (2020)
Němec Lubomír, Jebavá Marcela, Cincibusová Petra, Budík Pavel: A glass smelter with a conversion region for the conversion of glass batches to glass melts. Owners: GLASS SERVICE, a.s., Vsetín; the IRSM, Prague 6; the University of Chemistry and Technology in Prague, Prague 6.

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All the Institute's scientific departments made 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: Geological survey of a volcanic vein on the smallest of the Canary Islands, El Hierro, in an area dominated by the San Andrés giant landslide. Scientists from the IRSM explored the past, present and future behaviour of this giant landslide. Photograph: Jan Blahůt

3. Research projects conducted by the Institute's scientific departments in 2020

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.
- 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.

Projects financed by the Technology Agency of the Czech Republic:

- The material transformation of sewage sludge into a fertiliser with an increased phosphorus content.
- Interactive map of the seismic hazard in the Czech Republic.
- The geological environment and mineral resources
- Geophysics, geotechnics, geomaterials, geothermal energy in practice

Subprojects:

- The potential for the cracking of waste polyethylene into a mixture of hydrocarbons: the technological verification of a heat treatment method.
- The development of equipment for the coating of thin wires with biodegradable polymers from a solution.
- Partially pyrolysed composites as a light roofing material – the verification of climatic resistance and the optimisation of a suitable textile reinforcement material.
- A seismic beacon - a system for detecting temporal changes in the properties of a rock mass.
- A system for the automated evaluation of records obtained from a network.
- The optimisation of a system for the automated measurement, processing and interpretation of electro-resistance monitoring.

- Validation of the handling of used sorption materials based on activated carbon.

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
- Representation of the Czech Republic in the management of ICL 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 182 hours of teaching for bachelor courses and 172 hours for master's courses in the summer semester and 259 hours for bachelor, 178 hours for master's and 14 hours for doctoral courses in the winter semester. The institute trained 14 doctoral students, 2 of them from abroad. The staff of the department taught several courses in various fields during the year, especially at the Charles University – Faculty of Science and Faculty of Mathematics and Physics, the CTU – Faculty of Mechanical

Engineering, University of Chemical Technology – Faculty of Chemical Technology, Masaryk University in Brno – Faculty of Science, University of Ostrava – Faculty of Science, Jan Evangelista Purkyně University – Faculty of Science and the University of West Bohemia in Pilsen – Faculty of Education, as well as at a number of foreign institutions, e.g. Universidad Nacional de Cordóba Argentina - Faculdad de Ciencias Exactas, Físicas y Naturales.

The Institute shares two facilities with universities, i.e. with the Faculty of Science 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 Institute of Chemical Technology in Prague, the Technical University of Ostrava and Charles University - Faculty of Science.

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: PrimeCell Advanced Therapy a.s.
Contract: Research report on the characterisation of bioapatites.
The research report describes a procedure for the isolation of a mineral component (bioapatite) from a bone material (38 bone joint heads, both sexes with an age range of from 39 to 85 years) supplied by PrimeCell Advanced Therapy, a.s. and the evaluation of the chemical and physical properties of the mineral component. Concentrations of the major elements and substitutions of the minor elements were determined via chemical analysis methods including atomic absorption spectrometry, elemental analysis and photometry. The phase composition was evaluated via infrared spectrometry and X-ray diffraction, which also allowed for the determination of the degree of crystallinity. Further, physical properties such as the extent of the active surface area and helium density were evaluated together with the determination of the presumed in vitro behaviour employing the concentration of the free calcium cations in the medium. The report concludes with a set of statistically processed results and the characterisation of the chemical and physical properties of the bioapatites.
Application: Preparations containing bioapatite and demineralised bone tissue for the treatment of bone defects.

2) Commissioned by: Devro s.r.o.
Contract: Research report on collagen mass analysis.
The research report describes the evaluation of collagen mass samples following the various stages of the processing thereof by Devro, s.r.o., Jilemnice. The evaluation of the influence of the various treatment stages on the collagen samples from the input raw material to the final product included the use of image analysis technology, the qualitative determination of the chemical composition, the determination of the content of free water, fats, glycosaminoglycans, amino acids, nitrogen and the evaluation of the secondary collagen structure. The report concludes with an evaluation of the minimal impact of the techniques applied on the preservation of the native structure of collagen, the significant presence of inhomogeneities and the qualitative occurrence of metals and other inorganic elements in the collagen samples.

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

3) Commissioned by: UJP Praha a.s.
Contract: The pre-hydridation of Zr1Nb alloy samples.
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.

4) Commissioned by: DIAMO state enterprise, uranium mining and processing plant.
Contract: The determination of the pore distribution in rocks.
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.

5) Commissioned by: The National Institute of Standards and Technology (NIST), 100 Bureau
Drive, Stop 2300; Gaithersburg, Maryland 20899-2300.
Contract: A reference high-pressure CH_4 adsorption isotherm for zeolite Y: results of an interlaboratory study.
The study presents the results of an international inter-laboratory study led by the National Institute of Standards and Technology (NIST) involving the measurement of high-pressure methane adsorption isotherms on a reference material (NIST Reference Material RM 8850, Zeolite Y) at 25°C and up to 7.5 MPa. Twenty laboratories participated in the study, which provided more than one hundred methane adsorption isotherms on Zeolite Y. An empirical reference equation with a 95% uncertainty interval (Uk = 2) was determined from the data obtained. Thus, the various participating organisations replicated the high-pressure reference isotherm for carbon dioxide adsorption on the NIST RM 8852 (ZSM-5) reference material and demonstrated the usefulness of reference isotherms with concern to the evaluation of high-pressure adsorption measurements.
Application: A standard for analytical determination purposes.

6) Commissioned by: ČEZ a.s.
Contract: A set of expert reports on the seismic hazard faced by the Dukovany nuclear power plant.
Preparatory work for determining the current seismic hazard faced by the Dukovany nuclear power plant.
Application: Safety in the field of nuclear energy

7) 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 2.
An expert report for the requirements of the client and the Bukov Underground Research Facility (Bukov municipality, Vysočina region) which serves as a test site for obtaining data on the behaviour of the rock environment at the expected depth of the future Czech deep geological repository and for the in-situ testing of the materials being considered for the engineered barriers of the repository.
Application: Deep geological repository.

8) Commissioned by: ČEZ a.s.
Contract: Report on activities performed in 2020 for ČEZ a.s.
An interim report on a ČEZ project awarded under the SIGMA2 international programme entitled “The compilation of a fault database and the preparation of a methodological manual for the comprehensive assessment of faults as part of the assessment of seismic hazards”.
Application: The assessment of the seismic hazard faced by the company’s facilities.

9) Commissioned by: Temelín Power Plant II, a.s.
Contract: Report – The geomorphological analysis of the area around the Temelín power plant up to 25 km.
The revision of a report on the geomorphological analysis of an area 25 km around the Temelín nuclear power plant.
Application: Background information for the MISE 2022 report.

10) Commissioned by: Dukovany Power Plant II, a.s.
Contract: Report – The geomorphological analysis of the area around the Dukovany power plant up to 25 km.
The revision of a report on the geomorphological analysis of an area 25 km around the Dukovany nuclear power plant.
Application: Background information for the MISE 2022 report.

Cooperation with public administration authorities:

1) Commissioned by: City of Cheb.
Contract: An expert description of a potentially unstable section of a local asphalt road. The contract included the monitoring and description of a potentially unstable section of the road over a section with a length of approximately 40 m adjacent to building no. 72 (plot 22).

2) Commissioned by: City of Karlovy Vary.

Contract: An expert opinion on the state and progress of the stabilisation of a slope behind the Čas cinema. The contract included the assessment of the state and progress of the technical approach to the remediation of the slope located in the centre of Karlovy Vary.

3) Commissioned by: City of Karlovy Vary.
Contract: A final report on the post-remediation monitoring of a rock massif above road I/6 (E48) in Karlovy Vary. The evaluation of measurements using crack meters on a treated rock mass along a section of the road in Karlovy Vary.

Expertise:

1) Commissioned by: The Czech Highways Authority.
Expertise: Monitoring of the D8 motorway.
An IRSM expert conducted an evaluation of the stability of slopes along, and the overall safety of, the motorway as part of the activities of the D8 motorway monitoring committee.

2) Commissioned by: World Invest v.o.s., Jirkov.
Expertise: An expert opinion on the stability of the northern slopes of the Hutná u Hořetic valley in terms of slope movements.

3) Commissioned by: AZ Consult, a.s.
Expertise: The creation of a detailed digital terrain model of the D8 motorway in the N3 embankment area (SO A 210) and its immediate surroundings for the compilation of an overall geological model (a terrain model with an area of 0.6 km^2 using photogrammetry).

4) Commissioned by: The Czech Forestry Authority.
Expertise: An engineering-geological assessment of rock falls in the Svitavka valley: the evaluation of the stability of rock blocks and proposals for remediation measures. The various causes were subjected to analysis, the stability of the rock wall was assessed and the relevant remediation measures were submitted.

5) Commissioned by: ROCKNET s.r.o.
Expertise: Slope monitoring in Mlýnská street - Teplice. The stability of buildings in Mlýnská Street in Teplice was monitored and evaluated applying terrestrial laser scanning techniques.

6. International cooperation

The Institute participated during the year in 8 international projects, fulfilled professional assignments with concern to 6 international agreements and participated in 9 bilateral agreements on scientific cooperation with foreign partners. The staff of the Institute worked in 7 international scientific organisations, in two 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 Long Valley Caldera, California (2019 – 2022).
4) ICCP – Identification of Dispersed Organic Matter. International Committee for Coal and Organic Petrology, 2020.
5) ICCP – The evaluation of self-heating on coals of different rank via optical microscopy. International Committee for Coal and Organic Petrology, 2020.
6) MSM100462001 – Vanadium migration in coal regions: Sorption of vanadium on selected clay minerals (2020-2021).
7) Σigma-2 – R & D project on seismic hazards and ground motion, 2020.
8) European initiative Adria array – Understanding the Active Deformation of the Adriatic Plate and its Margins.

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 – 2022.
2) RNDr. Petra Štěpančíková, PhD: International Union for Quaternary Research, Commission on Terrestrial Processes, Deposits, and History. Vice president, term of office: 2019 – 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) Battelle Energy Alliance, LLC, Idaho.
   Theme: Batch-to-Glass Conversion and Chemical Durability of Glass for the Vitrification of Low Activity Waste (Contract No. 206349).
5) Battelle Energy Alliance, LLC, Idaho.
   Theme: Mathematical Modeling and Experimental Evaluation of a Melter Cold Cap for Nuclear Waste Vitrification (Contract No. 166789).

6) Uniwersytet Wroclawski.
   Theme: The research of the structural-geological conditions and construction of the Broumov/Góry Stolowe table mountains.
7) Naturhistorisches Museum Wien.
   Theme: The research of active tectonics in caves in the Eastern Alps.
8) Johannes-Guttenberg Universität Mainz.
   Theme: The radiometric dating of active tectonics in karst caves.
9) University of Memphis.
   Theme: The research of local seismicity.

In June 2020 the CE^{3}RN agreement on multilateral cooperation in the field of seismic monitoring and the research of earthquakes in Central and Eastern Europe (the Central and Eastern European Earthquake Research Network) was renewed.

7. Popularisation and public education activities

1) Excursion to the Department of the Structure and Properties of Materials of the IRSM:
   - Excursion to the geopolymers laboratory: presentation of the laboratory's activities to staff of the Joint Laboratory of Solid State Chemistry, University of Pardubice (IRSM, 23 January 2020).
   - Presentation of the IRSM's laboratories and the activities thereof for staff of VWR International Ltd. (Mgr. Ondřej Ženata) (IRSM, 15 June 2020).
   - Introduction to the IRSM's laboratories and the activities thereof for staff of DONAU LAB s.r.o., (Mgr. Štěpánka Mudrová) (IRSM, 21 July 2020).
   - Presentation of the geopolymers laboratory to sculptor Mgr. Jakub Rafl (IRSM, 30 June 2020).
2) A workshop entitled "Advanced diagnostic methods for the study of building materials" (Branišovice, 1 - 2 October 2020).
3) Exhibition: Unstable subsoil - landslides, lives and perspectives (VIPER gallery, Prague, 9 September – 31 October 2020).
4) Popularisation article: Jan Klimeš: Disasters conditioned by people. Vesmír (Space) 99, no. 12, p. 736, Prague, 7 December 2020.
5) Interview with Dr. Jan Klimeš: Landslides in the Peruvian Andes, Studio 6, Czech Television (17 February 2020).

8. Network monitoring

Monitoring 2
Monitoring network: SlopeNet:
Monitoring of slope deformations, landslides and rock falls.
Operator: the IRSM, RENS programme.
Activities: the geophysical and geotechnical monitoring of slope deformations with co-responsibility for monitoring.

Monitoring 3
Monitoring network: Network EU TecNet:
The 3D monitoring of tectonic structures in the EU.
Operator: the IRSM
Activities: meter readings, service and data evaluation.

Monitoring 4
Monitoring network: Czech Regional Seismic Network:
Earthquake monitoring in Europe and worldwide.
Operators: Institute of Geophysics AS CR, the IRSM, Institute of Geonics AS CR, Institute of Earth Physics, Masaryk university and the Charles University Faculty of Mathematics and Physics.
Activities: basic scientific earthquake research infrastructure, especially concerning long-term seismicity research in Europe and worldwide.

Monitoring 5
Monitoring network: MKNET:
Earthquake monitoring in the Lesser Carpathians.
Operators: the IRSM, the Earth Science Institute of the Slovak Academy of Sciences, Progseis s.r.o.
Activities: the continuous recording and evaluation of detailed research data on selected seismically active areas.

Monitoring 6
Monitoring network: REYKJANET:
The monitoring of earthquakes in Iceland.
Operators: Institute of Geophysics AS CR and the IRSM.
Activities: detailed long-term international research in a seismically active area of Iceland.

Monitoring 7
Monitoring network: Central Eastern Europe Earthquake Research Network.
Operators: the IRSM, Institute of Geophysics AS CR and 13 other institutions in Central and Eastern Europe under a CE^3RN contract.
Activities: The exchange of seismic data from earthquake monitoring in Central and Eastern Europe.

9. Published periodicals

1) *Acta Geodynamica et Geomaterialia*, Vol. 17, Nos. 1–4, 2020, 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. 64, Nos. 1–4, 2020, 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.).

Further sections of the Annual Report:
Financial statements: Profit and loss statement, 2020

Institute of Rock Structure and Mechanics of the CAS, v. v. i., V Holešovičkách 41, 182 09 Prague 8, Czech republic

Profit and loss statement

ID number
67985891

Balance as at 31. 12. 2020

According to Decree No. 504/2002 Coll.

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Item		Row	Activities		
Number	Designation		Main activity	Supplementary activy	Total
A	***A. Expenses***				
A.I	**I. Consumed purchases and purchased services**	**002**	**18 949 549,28**	**1 120 987,32**	**20 070 536,60**
A.I.1	1.Consumption of material, energy and other non-inventory items	003	7 439 456,12	575 712,15	8 015 168,27
A.I.3	3. Repairs and maintenance	005	3 870 571,14	4 933,88	3 875 505,02
A.I.4	4. Travel expenses	006	867 564,73	228 727,41	1 096 292,14
A.I.5	5. Representation costs	007	16 673,40	0	16 673,40
A.I.6	6. Other services	008	6 755 283,89	311 613,88	7 066 897,77
A.III	**III. Total personnel expenses**	**013**	**64 626 762,00**	**1 532 215,00**	**66 158 977,00**
A.III.10	10. Wages and salaries	014	47 737 324,00	1 139 322,00	48 876 646,00
A.III.11	11. Statutory social insurance	015	15 731 997,00	370 208,00	16 102 205,00
A.III.13	13. Statutory social expenses	017	1 157 441,00	22 685,00	1 180 126,00
A.IV	**IV. Total taxes and fees**	**019**	**66 543,00**	**0**	**66 543,00**
A.IV.15	**15. Taxes and fees**	**020**	**66 543,00**	**0**	**66 543,00**
A.V	**V. Total other expenses**	**021**	**4 102 473,59**	**1 170 588,90**	**5 273 062,49**
A.V.16	16 Contractual fines, delay interests, other fines and penalties	022	**130,88**	**0,00**	**130,88**
A.V.19	19. Exchange rate losses	025	67 069,87	0	67 069,87
A.V.21	21. Shortages and damages	027	761,70	0	761,70
A.V.22	22. Other expenses	028	4 034 511,14	1 170 588,90	5 205 100,04
A.VI	**VI. Total depreciation expenses, sold assets, addition and utilization to reserves and adjustments**	**029**	**15 354 561,88**	**0**	**15 354 561,88**
A.VI.23	23. Depreciation expenses of fixed assets	030	13 854 561,88	0	13 854 561,88
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**	**-11 730,00**	**0**	**-11 730,00**
A.VIII.29	29. Income tax	038	-11 730,00	0	**-11 730,00**
	Total expenses	**039**	**103 088 159,75**	**3 823 791,22**	**106 911 950,97**
B	***B. Revenues***				
B.I	**I. Total operating grants**	**041**	**85 243 986,85**	**0**	**85 243 986,85**
B.I.1	1. Operating grants	042	85 243 986,85	0	85 243 986,85
B.III	**III. Revenues of own services and merchandise**	**047**	**155 353,32**	**4 453 508,10**	**4 608 861,42**
B.IV	**IV. Total other revenues**	**048**	**17 994 717,98**	**0**	**17 994 717,98**
B.IV.5	5. Contractual fines, delay interests, other fines and penalties	049	47 790,56	0	47 790,56
B.IV.7	7. Interest income	051	21 946,42	0	21 946,42
B.IV.8	8. Exchange rate gains	052	23 042,94	0	23 042,94
B.IV.9	9. Settlement of funds	053	955 416,50	0	955 416,50
B.IV.10	10. Other revenues	054	16 946 521,56	0	16 946 521,56
	Total revenues	**061**	**103 394 058,15**	**4 453 508,10**	**107 847 566,25**
C	**C. Profit / Loss before tax**	**062**	**294 168,40**	**629 716,88**	**923 885,28**
D	**D. Profit / Loss after tax**	**063**	**305 898,40**	**629 716,88**	**935 615,28**

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