Characteristics of main research directions investigated at the institute and the achievements 2010−2014

Institute	Institute of Geology of the CAS, v. v. i.

The Institute of Geology of the CAS, v. v. i., is a public research institute with broad-scope scientific activities. It concentrates on the scientific study of the structure, composition and history of the Earth's lithosphere and the evolution of its biosphere. Although the Institute does not have the opportunity to cover all geological disciplines, its activities span a rich spectrum of problems in geology, geochemistry, paleontology, paleomagnetism and rock mechanics. The Institute takes part in the understanding of general rules governing evolutionary processes of the lithosphere and biosphere at regional as well as global scales. The Institute is also indispensable as a part of educational and popularization system in the national scale (for details see Appendix 3.3).

The Institute is a research institute of multidisciplinary character; nevertheless, the full range of geosciences is not summarized here. Specialized disciplines have been also developed in other geoscientific research institutions and faculties of universities in the Czech Republic, which is the platform for a broad and multi-branch co-operation with all geoscientific institutions within the Czech Republic and with number in abroad.

As has been proved historically, one of the main characteristic features of the Institute is its international co-operation. Not only with numerous subjects within Europe (EU, Visegrad Group, European Union Association Agreement Group etc.), but also worldwide (USA, Canada, Mexico, Japan, Korea, Brazil, Argentina, China, Russia etc.). Such cooperation allows the use of unique technical facilities that are not owned by the Institute.

The Institute has utilized a combined approach using a range of methods in different geoscience disciplines, such as: petrology and geochemistry of igneous and metamorphic rocks; lithostratigraphy of crystalline complexes; volcanology and volcanostratigraphy; structural geology and tectonics; paleogeography; terrane identification; taxonomy and phylogeny of fossil organisms; paleobiogeography of Variscan Europe; paleoecology (incl. population dynamics, bioevents); paleoclimatology as evidenced by fossil organisms and communities; biostratigraphy and high-resolution stratigraphy; basin analysis and sequence stratigraphy; exogenic geochemistry; exogenic geology, geomorphology; Quaternary geology and landscape evolution; karstology and paleokarstology; paleomagnetism; magnetostratigraphy; petromagnetism and physical parameters of rocks. This effort resulted in a participation in numerous foreign and international co-operations and, as a consequence, in a publication of peer-reviewed papers (often with impact factor – IF) in prestigious geological journals (ca 300 IF papers during 2010–2014) and also in other published (book chapters, books, conference proceedings) and unpublished outputs. The relatively wide range of specializations of the teams (and consequently also individual researchers) allows a co-operation in numerous joint projects supported by national and international grant agencies. The research areas are generally classified into 4 main areas, representing separate teams, but as was mentioned above, with the wide range of problems and topics, many of them are studied within co-operation among teams.

The history of the Institute dates back to 1960. During time, a relatively compact and stable structure of scientific units was constituted in response to different scientific needs and administrative requirements. Today, four main teams with different fields of research are delimited with more or less overlapping fields of research: (1) Department of Geological Processes; (2) Department of Paleobiology and Paleoecology; (3) Department of Environmental Geology and Geochemistry, and (4) Joined Department of Analytical Methods, Geotechnics and Paleomagnetism.

The first team (Department of Geological Processes) is focused on eight main research areas: (1) the composition and evolution of the Earth's mantle (a complex approach, including petrography, major/trace element and isotopic geochemistry and mineralogy of mantle-derived rocks such as peridotites, pyroxenites, eclogites and gabbros from different sites); (2) the structure, chemical composition and time evolution of Earth's Crust (team focused on the description of the origin and evolution of basaltic and calc-alkaline magmas); (3) Late Cretaceous and Cenozoic volcanism in the Bohemian Massif (Cretaceous and Cenozoic volcanism, its nature and evolution are studied in

combination of geochemical, mineralogical and tectonic methods); (4) geoarchaeology, Quaternary processes and paleoclimatology (interdisciplinary approaches that brought interesting solutions of various archaeological tasks); (5) sedimentology and stratigraphy (the team adapted and developed a modern complex of techniques which proved to be an effective tool for providing reliable proxies on climate, paleogeography and tectonic settings of the past); (6) transport and deposition of dust (centered around the transport and deposition of dust in geological past and present); (7) neotectonics and sandstone landscapes (determination of subsidence/uplift rates in sedimentary basins inferred from thermochronology, paleostress analysis and description of processes leading to the Recent formation of weathering crusts on sandstone), and (8) other research (different field that were not included in the topics above, such as element behavior, clay mineralogy, pedogenesis and others). For details see Appendix 3.5 of the first team.

The research focus of **the second team (Department of Paleobiology and Paleoecology)** is biosphere and its changes during geological history of the Earth, with four main research areas: (1) Paleozoic biostratigraphy and paleoenvironment (high-resolution biostratigraphy and relative dating of sedimentary rocks, development of biozonal scales, and complex biotic response to paleoenvironmental changes and global events using particularly graptolite and conodont faunas); (2) Carboniferous plants (palynology, systematics of spores and plant taxa and palaeoecological interpretations of Carboniferous tropical forests); (3) vertebrate paleontology (study of fish-like vertebrates, amphibians and mammals from different stratigraphic intervals, their anatomy, morphology, phylogeny, paleobiology and paleoecology, together with a description of new taxa); (4) Cretaceous research (study of Cretaceous biostratigraphy, micro and macrofauna, paleoenvironment, palaeoecology and sedimentary environments). Other areas of research are rather marginal or rather interdisciplinary-oriented and studied occasionally. Important is also the co-operation of the team with neontologists. For details see Appendix 3.5 of the second team.

The activities of **the third team (Department of Environmental Geology and Geochemistry)** lies in nine main research areas: (1) sandstone processes (study of morphological features related with "sandstone phenomena" in various size scales); (2) karst-related research (complex research of karst areas in various soluble rocks); (3) geomycology (study of fungi in geological processes); (4) environmental geochemistry of potentially toxic elements (study of environmental contamination with potentially hazardous elements such as arsenic, mercury and thallium); (5) environmental monitoring (monitoring of environmental fluxes and studies dealing with the dynamics of elements in the environment, together with monitoring activities of atmospheric deposition); (6) atmospheric transport of solid materials (role of natural dust and its possible effects on natural and social phenomena); (7) pedology (study of various pedological aspects, such as pedogenesis, soil hydraulic properties, soil structure, aggregate stability and others, in selected areas,); (8) the repository of radioactive waste materials including a study of possibilities of the disposal of high-level radioactive wastes into the geological formations, and (9) the analytical methods (comparison, improvement or development of various analytical techniques). For details see Appendix 3.5 of the third team.

The fourth team (Joined Departments of Analytical Methods, Geotechnics and Paleomagnetism) is in fact composed of small, similarly oriented research groups centering their interests on analytical approach of instrumentally measured data. The main research areas are: (1) paleomagnetic and rock magnetic investigations of the Prague Synform; (2) paleomagnetism and magnetostratigraphy of Cenozoic cave sediments in central Europe; (3) laboratory investigations and simulations of extraterrestrial materials; (4) magnetic scanning of volcanic rocks and multidisciplinary international studies; (5) landslide history recorded in a floodplain natural archive; (6) magnetostratigraphy of the Jurassic/Cretaceous boundary strata in the Tethyan, sub-Boreal and Boreal realms; (7) the estimation of stress-dependent anisotropy from P-wave measurements on a spherical sample; (8) rock elastic anisotropy determination by ultrasonic sounding and acoustic emission monitoring; (9) the influence of thermal heating on elastic wave velocities in granulite; (10) scale study of P-wave velocity anisotropy, crack distribution, velocity dispersion based on laboratory and field measurements; (11) the experimental and theoretical study of elastic wave field pattern in anisotropic texturized rocks; (12) the quantitative analysis of quartz deformation affecting the ASR in concrete; (13) the kinematic and dynamic anisotropy of sedimentary and crystalline rocks (ultrasonic, synchrotron and neutron diffraction studies); (14) the experimental study of crack initiation and crack damage stress thresholds as critical parameters influencing the durability of natural porous stone; (15) effects of long-

term natural irradiation on minerals; (16) moldavites and other tektites and impact glasses: composition, properties and origin; (17) the characteristics of the mantle sources and crystallization history of subvolcanic alkaline rock series the Roztoky Intrusive Complex, Ohře/Eger Rift (České stredohoří Mts.); (18) phase relations and crystallography of phases in the Fe-Nb-S, Re-Mo-S, and Ni–Sb–Te systems, and (19) new mineral descriptions. Analytical service for research projects is also a part of the duties within the Institute. For details see Appendix 3.5 of the fourth team.

Laboratory equipment has been constantly modernized and supplemented. The range of acquired analytical procedures performed at the mass spectrometer with laser ablation (LA ICP-MS Element 2, ThermoFischer) expanded owing to training of the operators. Besides laser ablation, trace element contents are routinely determined (including determinations on a commercial basis) from solutions after the decomposition of minerals, rocks and biological materials. REE contents are determined in a variety of minerals. Re-Os isotopes are also determined. U-Pb dating technique on zircons has been routinely introduced. ICP-MS applications were extended to serve the solution of environmental problems: measurement of trace element contents in natural waters, introduction of a method for the determination of Pb isotope ratios (i.e. $^{206}Pb/^{207}Pb$) in natural materials, and elaboration of a technique for the measurement of Hg speciation using the HPLC-ICP-MS method. Also, determination of trace elements in fossils was introduced using the LA ICP-MS system. Methodical procedures employ the TESCAN VEGA3 variable vacuum scanning electron microscope. The development of methodology also included, among others, an extension of the apatite fission track thermochronology method by age determination of rocks based on fission tracks after the decay of ^{238}U nuclei (FTA) in titanite. This method will allow dating of rocks which were exposed to temperatures not exceeding 310 °C during their history (120 °C in apatite). This method is conducted in co-operation with the Nuclear Physics Institute of the CAS, v. v. i. at Řež. The method of Th/U (U-series) dating of carbonates using ICP-MS has been introduced in cooperation with the Institute of Geological Sciences of the Polish Academy of Sciences in Warsaw. In 2014, a new instrument for carbon-coating and metal-sputtering Quorum Q150T ES was purchased to allow controlled deposition of conducting media on samples to be investigated with a scanning electron microscope or an electron probe microanalyzer. Control of deposited layer thickness is crucial for the preparation of specimens suitable for studies with instruments equipped with field emission sources or for back-scattered electron diffraction experiments. The GC (gas chromatographic unit) type Dani Master GC Fast Gas Chromatograph equipped with special column Zebron ZB-5 is an instrument primarily intended for speciation analysis of mercury. The new ICP EOS Agilent 5100 SVDV, acquired for the Department of Environmental Chemistry and Geochemistry is the top-range instrument, widely applied in analysis of composition and quantification of elements in the ppm/ppb concentration range. It is applied for routine analyses of macro-elements (Al, Ca, Fe, K, Mg, Mn, Na) in samples of natural water, being introduced to the market in 2014. It is equipped with a special semi-permeable multilayer mirror for a combination of intense signals with those of low intensity.

During the 2010–2014 period, the teams participated in many projects granted by the Czech Science Foundation (GAČR), the Grant Agency of the Academy of Sciences or by International projects (for details see Appendix 3.1). Although the number of grant proposals is growing (mainly to providers GAČR and Technological Agency of the Czech Republic – TAČR), success of the teams is relatively low. Such situation is a result of the generally underfunded science (as a whole, including budgets of main grant providers) in the Czech Republic, together with the fact that geosciences do not pertain to the "top" science fields supported by scientific policy of the Czech Republic.

Financial funding from private sources has been continuously decreasing since the year 2001. Numerous mining companies (often owned by multinational companies) are not interested in any type of research or development cooperation (which is carried by contract laboratories abroad – often owned by the company itself). The Institute can reach just lower-budget contracts based on personal contacts.

Nevertheless, even though the Institute is underfunded and loaded by numerous administrative requirements, the teams are able to produce high-quality results. It is also necessary to mention that all results are annually published as research reports in printed and on-line versions (for details see https://www.gli.cas.cz/en/annual-reports).

Research Report of the team in the period 2010–2014

Institute	Institute of Geology of the CAS, v. v. i.

Scientific team	Department of Geological Processes

The team has utilized a combined approach using a range of methods in petrography, mineralogy, geochemistry and geochronology. This effort resulted in a participation in several foreign and international projects and, as a consequence, in a publication of impact factor (IF) papers in prestigious geological journals (ca. 97 IF papers during 2010–2014) and also in other outputs (book chapters, books, conference proceedings). The relatively wide range of specializations of the team members allows effective cooperation in joint projects supported by national and international grant agencies (listed below). Members of the team have been cooperating with a number of scientists and institutions from abroad for many years. Among them, Prof. L. G. Medaris (University of Wisconsin-Madison, USA), Prof. W. Siebel (University of Tübingen, Germany), Prof. Ernst Hegner (University of München, Germany), Prof. Jaroslav Dostal (Saint Mary's University, Canada), Associate Prof. Theodoros Ntaflos (University of Vienna), Assistant Prof. Michael Bizimis (University of South Carolina), Prof. Takao Hirajima (Kyoto University), Dr. Virginia Toy (University of Otago, New Zealand), Prof. Michael T. Whalen (University of Fairbanks, Alaska, USA), Prof. Fréderic Boulvain (University of Liège, Belgium), Dr. Axel Müller (Geological Survey, Norway) represent the most important collaborations, which resulted in publications of joint papers that are listed and commented below. The IF papers are classified into 8 separate areas of geoscientific research.

Research Area 1 – Composition and Evolution of the Earth's Mantle

The mantle forms the largest mass of the Earth, and processes occurring within the Earth's mantle such as partial melting and metasomatism are crucial for the formation of the crust. Therefore, the understanding of its composition and evolution through time is very important to provide constraints on the Earth's history. The main focus of the study by the team is represented by a complex approach, which includes petrography, major/trace element and isotopic (Sr-Nd-Hf-Os-Cr-O) geochemistry and mineralogy of mantle-derived rocks such as peridotites, pyroxenites, eclogites and gabbros from different localities in the Czech Republic, Germany, Austria, Argentina, Turkey or Japan. During 2010–2014, collaborative studies on mantle-derived rocks with several institutions from the Czech Republic and abroad (USA, Japan, Germany, Austria) resulted in publication of 10 papers in IF journals, 1 book and 1 book chapter. In all IF journal contributions, the team performed sampling, obtained and interpreted mineralogical and geochemical data, and largely contributed to writing. Two of the IF papers (IDs 388153, 399281) represent complex petrographic, geochemical and mineralogical research of mantle xenoliths (peridotite, pyroxenite) from the Bohemian Massif (Czech Republic, Germany) hosted by Cenozoic volcanic rocks. The team has a key role in these papers as it initiated the studies, managed the activities, participated in sampling, obtained most of the whole-rock and mineral data and wrote the majority of the text including the discussion. Another paper (ID 397230) was focused on unique symplectite-bearing pseudomorphs after garnet found in mantle xenoliths in NE Bavaria: the team contributed to this study in sampling, obtaining trace element data on garnet symplectites and writing in all manuscript sections dealing with trace element geochemistry. Two papers (IDs 337938, 350018) originated as a result of extensive and long-term co-operation with Japanese colleagues. They describe structural, mineralogical and P-T evolution of spinel/garnet peridotites and eclogites from the Bohemian Massif. The team contributed to this research in geological description and final interpretation of petrographic results in the frame of the European Variscan orogenic belt. Two studies (IDs 346334, 356767) deal with the composition and evolution of mantle-derived gabbroic rocks associated with the Moldanubian Pluton and West Bohemian shear zone, respectively. In both cases, the team has a dominant role as it initiated the studies, obtained rock samples and most of the whole-rock and mineral

data, and wrote the majority of the text including the discussion. A close co-operation with U.S. colleagues resulted in one paper (ID 388155) focused on highly siderophile element geochemistry and Re-Os isotopic compositions of peridotites and pyroxenites from eastern Bohemia. The team has a crucial role in this study providing all of the well-characterized samples, obtained geochemical and mineralogical data and wrote most sections of the manuscript. Extensive collaboration between several institutions resulted in a paper dealing with Cr isotopic composition of the Earth's mantle (ID 399326). In this study, the team provided well-characterized samples and interpreted data available on these samples. The last paper (ID 330752) is focused on the structure of the lithosphere in the western part of the Ohře/Eger rift. The team contributed to this study interpreting geophysical data in the broad geological context in this area. The book (ID 377912) presents the PhD. thesis of Lukáš Ackerman, which was accomplished at the Institute of Geology of the CAS, whereas the book chapter (ID 360821) described the first occurrence of a microdiamond within mantle rocks from south Bohemia.

Research Area 2 – Structure, Chemical Composition and Time Evolution of Earth's Crust

The Earth's crust is a thin dynamic layer that varied in both thickness and composition through time. The team focused on the description of the origin and evolution of basaltic and calc-alkaline magmas. Distinction is made between basaltic magmas and the calc-alkaline suite of magma derived from the sialic crust and its sedimentary cover. A complex approach including petrographic description, isotope geochemistry, dating of minerals and mineralogy is an effective tool for providing a detailed description of the Earth's crust and thus, the team published 31 similar studies in prestigious geological journals with IF, 3 books and other publications during the 2010–2014 period. Owing to the possibility to produce analytical data using the laser ablation ICP-MS system, the team played a key role in IF publications, giving the first description of the dependency behaviour of trace elements in quartz from plutons of different geochemical signatures. There are small differences in quartz from weakly differentiated plutons, but quartz from the highly fractionated granites differs significantly (IDs 382712, 392584, 432589). Geochemically different types of two contrasting magma types, orogenic S-type and anorogenic A-type were described in papers from the Bohemian Massif, where the team performed sampling, obtained most of the whole-rock and mineral data and wrote the majority of the text including the discussion (IDs 382702, 383498, 397207, 397209, 427394). In the same topic for different rock type – pegmatites – the team performed discussion of trace element distribution and improved discussion (ID 389603) and also recapitulated pegmatite summary localities book (ID 356987) from the Bohemian Massif. The team cooperated with German colleagues on the description of differences in volcanic activities (ID 388840) at the border between Saxony (Germany) and northern Bohemia (Czech Republic), whereas implications for magma emplacement mechanisms were described in ID 367548. Two complex granitoid studies including new huge data sets were completely prepared by two doctoral students from the team (IDs 434872, 439554). Several papers dealing with the time evolution of igneous rocks or provenance studies were produced at the Bergen University in Norway. A member of the team prepared analytical data and participated in writing of sections dealing with U-Pb dating of zircons. The first manuscript was structural and geochemical study of two granitoid plutons in the Teplá-Barrandian Unit (Bohemian Massif; ID 348397), while similar analytical approach was employed for granites from the Krkonoše-Jizera plutonic complex (ID 422135). The U-Pb zircon provenance ages based on a huge set of analytical data performed in Norway was focused on Moldanubian metasediments in the Bohemian Massif (ID 424604) and in the Kaoko Belt in Namibia (ID 399224). A complex study prepared by a team member in Norway presents a comprehensive provenance data set for sedimentary sequences of E Greenland and Jan Mayen Fracture Zone. Data are used to discuss the evolution of sedimentary sequences in E Greenland and the link to offshore sediments located between Greenland and Norway landmasses (ID 361338). Also high-pressure and high-temperature rocks were dated using the laser ablation U-Pb technique, and the mechanism of zircon (re)crystallization during short-lived, high-P granulite facies metamorphism in the northern Bohemian Massif was described (ID 432956). The first complex study, where the team performed sampling, all analytical U-Pb laser ablation data from the equipment housed at the IG CAS, and an additional study of Re-Os isotopic data of related molybdenite mineralization were performed in cooperation with colleagues from another team at the Institute (ID 438187). Contribution of Re-Os geochemistry and geochronology of crustal gabbros was completely under the leadership of a team member in study ID 396218, while Re-Os geochronology data of the team served as a basis for the description of molybdenite U-Mo deposit in the Western

Carphatians (Slovakia) ID 399301. The study of fluid inclusions in quartz from the gold deposits in the Bohemian Massif was completely under leadership of a team member as part of doctoral thesis (ID 358377). The paper (ID 360768) results from the running joint bilateral Czech-Japanese project dealing with highly metamorphosed rocks from southern Bohemia. The team contributed to this research in sampling and interpretation of main trace element data, and the model of the evolution of *HP-HT* rocks from the Moldanubian Zone. The measured dataset of porosity, effective diffusion coefficient and hydraulic conductivity was used in safety assessment calculations for a deep (>400 m) radioactive waste repository. Petrographic descriptions of 45 granitic samples from the Bohemian Massif, Czech Republic, were included by a team member (ID 392203). Two mineralogical and petrological descriptions by the team members were included in the studies of metapelites and veins from the Federico Units in the Internal Zone of the Rif, Spain (ID 340581) and Western Carphatians (ID 368899). The effects of late-stage hydrothermal events with a detailed clay mineral study were performed by a team member in topaz-bearing granites from the Bohemian Massif (ID 432729). The main author of the team accomplished all the steps towards complex geochemical characteristics of clastic metasediments of the Teplá Crystalline Complex that are consistent with the model of incorporation and preservation of arc-derived sediments in a Cadomian accretionary wedge (ID 442177). Two members of the team applied their long-term experience with crustal basement and Carboniferous and Permian cover, respectively, into a comprehensive book of the geology of the Bohemian Massif (ID 345662). Fission-track dating of apatites and time-temperature modelling of exhumed rocks by a member of the team were contributions to geomorphological study from the Makalu–Barun region in the East Nepal Himalayas (ID 434001).

Research Area 3 – Late Cretaceous and Cenozoic Volcanism in the Bohemian Massif

In the Bohemian Massif, the Cenozoic volcanism (~30 to 0.26 Ma) is widespread, forming two major volcanic areas: the České Středohoří Volcanic Complex (CSVC) and the Doupovské Hory Volcanic Complex (DHVC) located in the Ohře/Eger Rift. These two complexes are accompanied by smaller volcanic fields and numerous solitary occurrences of variable age. Furthermore, much less common Cretaceous volcanic rocks also occur. Nature of the magma sources and evolution of parental magmas provide constrains on spatial and temporal heterogeneity of the upper mantle beneath the Bohemian Massif and processes leading to magma modification during its ascent. The team combines geochemical, mineralogical and tectonic methods. During 2010–2014, collaborative studies on mantle-derived rocks with several institutions from the Czech Republic and abroad (Germany, UK, Hungary) resulted in publication of 11 papers in IF journals and 1 book chapter. One of the most important contributions is the highly cited paper providing a review of recurrent Cenozoic volcanic activity in the Bohemian Massif (ID 358374). Long experience of the team with the Bohemian Massif volcanism played a key role as it enabled the initiation of this study and writing of the most important sections of the text. Four papers (IDs 350041, 399286, 399310, 427392) deal with petrography, mineralogy, mineral chemistry and major/trace element geochemistry together with Sr-Nd isotopic geochemistry of effusive and subvolcanic rocks of the Ohře Rift, Krušné Hory/Erzgebirge Mts. and northern Moravia. The team has a crucial role in these contributions as it initiated the studies, sampled the rocks, managed the activities and obtained/managed whole-rock and mineral data and wrote the main sections of the text including the discussion. Extensive studies on the tectonic settings of the CSVC and Late Cenozoic volcanic rocks in the Moravia-Silesia region were initiated by the team, which also provided field data measurements and interpretation of data. This approach resulted in two papers (IDs 356918, 382559). With the close co-operation with German colleagues, mineralogical studies of alkali basalts from the Ohře Rift as well as related placer deposits were carried out (IDs 382716, 432618). The team provided all samples for these studies and interpreted measured data in the wide geological context. One paper (ID 333102) deals with rare occurrences of radiobarites from the Cenozoic volcanic area in the Bohemian Massif. In this specific study, the team performed sampling, interpreted measured data and wrote the most important sections of the manuscript including discussion. The last contribution (ID 340715) provides magnetic data on a suite of Ti-rich basalts from the Krušné Hory Mts. where the team provided all well-characterized samples and geochemical framework. The book chapter (ID 428188) presents a comprehensive review on Late Cretaceous to Quaternary volcanism in the Bohemian Massif.

Research Area 4 – Geoarchaeology, Quaternary Processes and Paleoclimatology

Geoarchaeology represents a relatively new interdisciplinary approach, which brought interesting solutions of archaeological tasks during the last few decades. The applied methodological approaches are largely similar to those used in Quaternary geology and paleolicmatology. During the period of 2010–2014 the team members were involved in several sedimentological, palaeoclimatological as well as geoarchaeological projects. One of the main roles of the team was multi-proxy research often connected with archaeological tasks. The research areas are located in the Czech Republic as well as abroad (Egypt, Sudan, Slovakia, Austria, Germany, Poland) and funded mainly by the Czech Science Foundation, Academy of Sciences as well as by foreign universities. Long-term projects run the central European space were concerned mainly with formation processes of archaeological structures (for example, Neolithic rondels, temporary Roman camps, Medieval bailey in alluvial plain in Veselí nad Moravou or Early Medieval site at Roztoky). In each case, sedimentological and micromorphological evaluation together with geochemical proxies were used to track formation processes active in sediment deposition. Interesting was, for example, a comparison between the formation processes of spitzgrabens appearing in Neolithic rondels and those in short-term Roman camps. Sedimentological and micromorphological approach was the key one to answer questions about the way of infilling. Wooden structures found in an alluvial plain at Veselí nad Moravou were studied by environmental approaches also including sedimentology and micromorphology. This record provided interesting information about the maintenance processes of the horse stable as well as the vegetation history of the study area (ID 438183). Long-term research at the Early Medieval site at Roztoky, which included intensive international cooperation, shed new light on the formation processes of sunken house infillings (ID 373161). Tasks transitional between classical Quaternary geology and archaeology are typical in Palaeolithic archaeology. The team members were involved in sedimentological as well as geoarchaeological research conducted in the context of Gravettian occupation in Moravia during the last few years. New conclusions were achieved on the Gravettian occupation strategies (ID 392201) as well as the regional environmental conditions of Gravettian sites in Moravia (ID 438582). The long-term projects solved by the team within Central Europe as well as in Northern Africa are also connected with the hot issue of the last climatic cycle. The studied sedimentary archives which provided the data for research come mostly from lake deposits in Egypt and the Czech Republic, loess with paleosols in the Czech Republic, Poland, Austria and Germany or alluvial deposits in the Nile River basin or the Czech Republic. These studies concern the research of Pleistocene and Holocene deposits. Pleistocene deposits are represented mainly by loess which records the last climatic cycle (IDs 396663, 391031); the team provided mainly sedimentological analyses within these studies. Another Pleistocene sedimentary archive studied by the team members are glacial deposits. Micromorphology of quartz grain surfaces was the methodological tool applied in this type of research (IDs 340571, 375751). Holocene deposits studied by the team members are mainly fluvial and lake deposits. Nile deposits were studied in cooperation with Sudanese team with the aim to solve questions connected with the agricultural influence of the alluvial zone (ID 377902). Similar topics were addressed by the project on the development of alluvial record in Strážnické Pomoraví (IDs 343577, 365646) and Elbe River basin in the Czech Republic (ID 434168). The role of the team was again mainly sedimentological and micromorphological research including geochemical and magnetic proxies. Sedimentary record of lakes studied by the team members provided a new insight into the Holocene record of Central Europe (ID 424766) and, among others, an interesting information about the seasonal function of the lake in the context of burial rites used in the Egyptian Empire (ID 377898).

Research Area 5 – Sedimentology and Stratigraphy

With the aim to understand the conditions governing processes on the surface of the ancient Earth, the team adapted and developed a modern complex of magnetic-susceptibility–gamma-ray-spectrometry–geochemistry (MS–GRS–GC) techniques which proved to be an effective tool for providing reliable proxies on climate, paleogeography and tectonic settings of the past. This approach is based primarily on petrophysical outcrop logging of marine carbonate sequences that provide great archives of the once delivered aquatic and aeolian impurities. This has something in common with the well-known case of impurity archives in ice; with marine carbonate rocks, however, we can reach much older time periods, even several hundred million years ago. Our team has a leading reputation of a founder’s workplace and a one having one the most extensive technical practice in the world. This was

recognized with the joint UNESCO and IUGS Project 580 (2009–2013, 2014 O.E.T.). In this global project, our representatives were international co-leaders. The work of the team is almost exclusively connected with our own technical facilities and personnel, although the domestic integration and cooperation among the groups worldwide is also our important strategy and priority, so that adequately strong teams could be also constituted in Belgium, U.S., P.R. of China or elsewhere (ID 432546). The main part of the current studies relates to the Devonian period between 359 and 419 million years ago. Vertical and lateral structures of environmental mosaics together with the identification of related geological processes on the Earth were particular subjects of the studies. These studies addressed, e.g.: the different conditions on both hemispheres with implications for the improvement of stage boundaries, bioprovinces, and climate settings (ID 376517); a comparison of our first detailed 20 Ma "long" composite section from Moravia (CR) with its Belgian counterpart (ID 345505); multifaceted analysis of the Lower–Middle Devonian settings combining data from the peri-Gondwanan and Laurussian areas, which means in the present configuration of terranes across the continents of Asia, Europe and North America (IDs 359029, 383933, 345507). The other extensive MS–GRS–GC studies focused on the classical area of stratigraphy with many internationally approved "standards" – the Barrandian area: here, the frontiers of knowledge in the discipline were pushed forward by analysis of rock composition and its regional and global interpretation (IDs 342126, 345504, 346371). Since the biota has a significant role in environmental change, and biotic evolution provides the primary time network, the disciplines of sedimentology and stratigraphy are interconnected. In this context, e.g., a new subdivision of the Lochkovian Stage was accomplished (ID 382710). The work with logs must also cope with the great but often underestimated variability of the records which contain many gaps and vary in "time or speed". To handle these problems, dynamic time warping (DTW) techniques from the sphere of speech recognition were adapted and introduced into geology (IDs 345501, 376517). The MS–GRS–GC complex of techniques was also employed to understand the Mesozoic (ID 392582) to Recent environments and processes. It can be stated that the number of possible applications and co-operations rapidly expands. Another "big" theme designed and solved by members of the team was the experimental sedimentology with the employment of rheology and fluid mechanic, under co-operation with the Institute of Chemical Process Fundamentals of the CAS. Here, we can refer to two major outputs: one is about arching structures in granular sedimentary deposits (ID 392958) and the second treats the conditions for telescoping of tiny hollow cones (ID 429385). Although a strong preference was given to the above mentioned two themes, the range of our research projects and interests was larger: it can be exemplified by the studies on blackening of bioclasts (ID 389354), revision of some groups of Protozoa with complex life cycle affecting the sediment fabrics and composition (ID 398410), as well as contributions to the books on Cenozoic coal basins (ID 357079) or overall research progress under the auspices of the International Geoscience Programme (IDs 428183, 428181).

Research Area 6 – Transport and Deposition of Dust

The team benefits from the experience with transport and deposition of dust in geological past as well as from the employment of the methods typical for petrology, mineralogy, geochemistry and analysis of organic detritus. The essential capacity of the team is rooted in the Department of Geological Processes but penetrates through all other institute research units, other Czech and World institutions (e.g., in environmental and atmospheric sciences). The main contribution of the team consists in the use of advanced analytical and interpretation methods for the mineral dust of silt- and fine sand-size categories. Possibly the greatest discovery of the team was the finding that a significant part of atmospheric dust load (and also deposit) related to "coarse" dust is inaccurately measured and remains undetermined or tentatively classified. Evidence of this fact was found by means of "sediment traps" where the real sediment from wet or dry deposition was collected. It is mainly due to the fact that most of the standard dust-monitoring procedures "in air" are not sensitive enough to the presence of scattered but very important particles tens or even hundreds of micrometres in size. Due to presence of porous and complex shaped and/or aggregate "light" particles, the seemingly oversized particles can escape also the models being transported for hundreds and thousands of kilometres across the globe. This has many consequences related to the change of these particles during transport, deposition and after the deposition. Evidence of the evolution and mixing of dust particle sources and populations in air is also very interesting. According to new findings, the "Geological Dust Team (GDT)" provided a reinterpretation of data on the recent and present-day inputs of the individual natural dust components

into the sediments. The average dust deposition flux modified with regard to the amounts of dust material really preserved in stratigraphic record was published for the first time (ID 345506). Continued and laborious studies on the African, Scythian and Asian dust delivery episodes over the Czech and European countries including the studies on mixed natural and man-made dust particles are reported at conferences and in media. The same relates to the findings of long-distance transport of volcanic ash from the 2009 eruption of the Alaskan Mount Redoubt volcano or from the 2011 Grímsvötn eruption on Iceland. The evolution of mixed dust deposit in the Czech Republic was given much attention after the 2010 eruption of Iceland's Eyjafjallajökull Volcano. The results of our studies suggest that volcanic dust usually represents only a few percent in the deposit but considerably contributes to the aggregation, burdening and deposition of dust. The sizes of really deposited volcanic ash particles were also in excess of the limits provided by current models for atmospheric transport of volcanic ash. The team co-operated with scientists from Charles University, Czech Geological Survey and with Icelandic volcanologists, and the paper was published in 2013 (ID 392114). This led also to strengthening of the co-operation between the GDT and Icelandic research institutes. In the studies from the second half of the assessed period, we were also dealing with "volcanic dust" (not only fresh volcanic ash) because significant amounts of the emitted and transported dust originate from volcanic deserts with material from historical eruptions. One study worth of mentioning contains measurements and documents showing how dust emissions can be effective even on wet fluvio-glacigenic tephra plains: the mechanism is based on thermal gradient and strong "hoovering" by dust devils and even tornado swarms (ID 432640).

Research Area 7 – Neotectonics and Sandstone Landscapes

Petrographic and tectonic studies of sandstones yield data on their reservoir properties (groundwater and hydrocarbons) and their changes due to burial and compaction, hydrothermal alteration, and brittle tectonic deformation. Sandstones provide the key to the recognition and quantification of subsidence and uplift of sedimentary basins, faulting of basin margins and basin inversion. The weathering forms now observed on sandstone reflect environmental changes during the Pleistocene and Holocene. The three directions of study pursued by the team are: (1) determination of subsidence/uplift rates in sedimentary basins inferred from thermochronology: apatite fission-track analyses; (2) refinement of the succession of paleostress fields transmitted from the Alpine thrusting front to its foreland in Late Cretaceous and post-Cretaceous times based on the paleostress analysis, and (3) description of processes leading to the Recent formation of weathering crusts on sandstone and to the variety of micro- to mesoscale weathering forms on sandstone; this direction mostly employs petrographic/SEM study and porosimetry study. In direction 1, the team of the Department of Geological Processes conducts the research in all its aspects. In direction 2, the research is contributed by scientists from the IRSM CAS. In direction 3, a wider collaboration between the teams of the IG CAS exists, being also contributed by a scientist from the IRSM CAS, but coordinated by the team of the Department of Geological Processes IG CAS. In the 2010–2014 period, thermochronology studies focused on the reconstruction of burial histories of different parts of the Bohemian Cretaceous Basin and its source areas from traces of spontaneous uranium fission in apatites isolated from sandstones within the basin *vs.* those isolated from crystalline rocks in the source area. Preliminary results indicate a rapid cooling/uplift of basinal sediments in the latest Cretaceous, contrasting with slow cooling rates of the source areas lasting till the present but accelerated in the last 20 Ma; these results were compared with the uplift history in the Karakoram Mts. (ID 432583). The study of tectonic deformation and paleostress history of the Alpine foreland centred around the Lusatian Fault and the adjacent areas of the Bohemian Cretaceous Basin. The results were published in one IF paper (ID 429784) with another one accepted for publication in 2015, and in several refereed journals (IDs 382867, 426651) with the team members being the main authors. As a prime result, a new chart of Late Cretaceous and post-Cretaceous paleostress fields was proposed for the Bohemian Massif. A discussion of the time relation between the identified paleostress fields and periods of volcanic activity was presented in another IF paper (ID 358374) and became the basis of another paper dealing with the structure of the Ohře Rift graben (ID 356918), both resulting from within-team cooperation with volcanologists. Knowledge of the superposition and timing of the acting paleostress fields in post-Cretaceous times proved useful in the finding of favourable parameters for the origin of densely jointed and faulted zones now activated by mass movements. This approach contributed to the explanation of the origin of a huge landslide in the České středohoří Mts. volcanic area (ID 430476) and at a rock castle in sandstones (ID 353913). Even

more importantly, indications of the effects of the latest paleostress fields are used as one of the factors to be considered in siting of nuclear installations: in this respect, the team collaborated with the State Office for Nuclear Safety in formulating methodical approach to evaluation of nuclear safety and provided expertise on one of the sites (ID 422463). The study of the relation between petrographic properties of sandstone – most notably cementation and porosity – and weathering relief resulted in a number of conference contributions (11th International Symposium on Pseudokarst at Saupsdorf 2010; 2011 GSA Annual Meeting in Minneapolis; Sandstone Landscapes Conference at Kudowa Zdrój 2012; 16th International Congress of Speleology in Brno 2013) and stimulated international cooperation with German and Polish colleagues (e.g., IDs 394176, 394181, 394898). A guidebook on this topic was prepared for the 16th International Congress of Speleology in Brno (ID 394380) and a book summarizing the present state of knowledge aimed at wider professional public was published at Academia Publishing House in 2010 (ID 342183), with a chapter in the book on a specific landform of the Pravčice Arch shortly following (ID 345002). An IF paper on the classification and origin of weathering crusts on sandstone was published in 2011 (ID 359012). Research on the weathering forms on ferruginous sandstone (ID 353991) and carbonate-cemented sandstone (ID 367382) resulted in the formulation of a paradigm on the origin of symmetrical cavities in sandstone in an IF paper published in 2015.

Research Area 8 – Other Research

There are several IF papers, where cooperation of the team resulted in publications, which are beyond the scope of the above mentioned research areas. Cooperation with colleagues from Charles University yielded two papers, where a member of the team contributed with his knowledge of element behaviour (IDs 434418, 388152). Knowledge of clay mineralogy of a team member produced, in cooperation with colleagues from the Institute and other experts, papers focused on pedogenesis studies from the Bohemian Massif (IDs 386578, 390445, 424598, 434627). Knowledge of element behaviour in *HP-HT* conditions led, in cooperation with a member of another IG CAS team, to a formulation of a diffusion model in binary systems (ID 388529). Contributions of geologic descriptions by the team members with biology topic were included in a geobiology publication (ID 432731), while participation of the team members resulted in publications focused on mineralogy (ID 389392), textural analysis (ID 399206) and geophysics (ID 434534). In these investigations, the team members usually provided analytical, textural and/or geophysical data, and largely contributed to their interpretation. Five books have been published with a significant contribution of the team, which are the co-editors of these publications. The most important books include soil micromorphology (ID 427398) or atlas of clay minerals (ID 441700). The team was also involved in secondary school education writing a textbook on chemistry of transition metals (ID 424529). The team successfully introduced U-series dating of cave deposits using analysis in liquid samples – measurement of isotopic ratios of U and Th using the ICP-MS technique. The accuracy of the U-Th measurement were compared to earlier age~depth models based mostly on α-spectrometry and showed significantly more precise time-scale results for stable isotopes records. The preliminary data was applied to natural samples of speleothem calcite from Czech, Polish and Slovakian caves (ID 434900).

During the 2010–2014 period, the team participated in several projects granted by the Czech Science Foundation (A); the Grant Agency of the Academy of Sciences (B) or by International projects (C). Listed are projects, where members of the team participated as principle investigators or co-investigators.

(A): *No. 202/08/0767*: Neutron texture analysis of carbonates and gabbros; *No. 205/09/1170*: Upper mantle beneath neovolcanic zone of the Bohemian Massif: xenoliths and their host basalts; *No. 206/09/1564*: Multi-proxy paleoecological study of unique sediments from the former Komořany Lake, Most Basin, Czech Republic; *No. P210/10/1105*: Trace elements in igneous quartz – frozen information about silicite melt evolution; *No. P210/10/1309*: Behaviour of geochemical twins Al/Ga and Si/Ge in different types of acid silicate melts; *No. P405/11/1590*: Neolithic rondels from the perspective of micromorphologic and formative analysis; *No. P405/11/1729*: Medieval Castle in alluvial plain; *No. GA13-15390S*: Re-Os geochronology of ore mineralizations from the Bohemian Massif with possible metallogenic implications; *No. 14-13600S*: Rock textures and mineral zoning: Insights into open system processes in granitoids.

(B): *No. IAA 300130612*: Combined magnetostratigraphic studies of Cenozoic volcanics, Bohemian Massif; *No. IAA300460602*: Upper crustal model of the Ohře Rift and its vicinity; *No.*

IAA300130702: Growth rhythms as an indicator of the Earth's rotation and climate changes in the geological past; *No. IAA300130801*: Chemical evolution of contrasting types of highly fractionated granitic melts used melt inclusions study; *No. IAA300130806*: The concept of micro- to mesoscale sandstone morphofacies in the temperate zone; *No. IAAX00130702*: Hydrodynamic concept of stromatactis formation in geology; *No. KJB300130902*: Highly siderophile element and Re-Os isotope geochemistry of mantle pyroxenites: implications for mantle refertilization.
(C): *International Geoscience Programme (IGCP) of UNESCO & IUGS, Project Code IGCP No. 580*: Application of magnetic susceptibility as a paleoclimatic proxy on Paleozoic sedimentary rocks and characterization of the magnetic signal; *Bilateral co-operation between Institute of Geology of the ASCR and Russian Academy of Science (Institute for the History of Material Culture of Russian Academy of Science, Stone Age Archaeology Department), Sankt Peterburg, Russian Federation*: Cultural adaptations to natural (climatic) fluctuations in the Upper Palaeolithic of Eastern (Kostenki group) and Central Europe (Moravian group); *Grant-in-aid internal program of international cooperation projects Academy of Sciences of the Czech Republic, Project Code: M100130904*: Polyphase evolution of the highly metamorphosed rocks in collisional orogens: an example from Bohemian Massif (Czech Republic); *International Geoscience Programme (IGCP) of UNESCO & IUGS, Project Code IGCP No. 596*: Climate change and biodiversity patterns in the Mid-Paleozoic (Early Devonian to Late Carboniferous); *Program Mobility supported by the Ministry of Education, Youth and Sports, Project Code: 7AMB 12AR024:* Thermochronologic constraints on the evolution of eastern Magallanes foreland basin sediments; *Grant-in-aid internal program of international cooperation projects Academy of Sciences of the Czech Republic, Project Code: M100131203*: Origin and characterization of mantle and crustal rocks: answer for deformation, thermal and geochemical evolution of orogenic zones.

Research Report of the team in the period 2010–2014

Institute	Institute of Geology of the CAS, v. v. i.

Scientific team	Department of Paleobiology and Paleoecology

The **Department of Paleobiology and Paleoecology** has been established as a multidirectional scientific unit where all age categories of researchers are present; as it reflects the balanced age structure of the team. As a substitute for some colleagues that have received an emeritus status, two PhD students joined the department last year. Intense collaboration with other scientific units both inside and outside the Institute is characteristic of the Department because of broad application of paleobiological data in geological and biological fields. Accordingly, the Department of Paleobiology and Paleoecology is not narrowly oriented and/or strictly limited to one direction but stands as an open unit strategically positioned at the intersections of many scientific disciplines and research topics. Among principal paleontological specializations, palynology, vertebrate paleobiology, marine micropaleontology and ichnology are represented by relevant specialists. The department is focused on four main research areas – Paleozoic stratigraphy and paleoenvironment, Carboniferous plants, Vertebrate paleontology and Cretaceous research – that can be further subdivided into various sub-topics. The members of the Department of Paleobiology and Paleoecology have been working on specific topics with a number of specialists from foreign scientific and/or academic institutions: C.E. Mitchell (State University of New York at Buffalo, USA), S. C. Finney (California State University, Long Beach, USA), M. J. Melchin (St. Francis Xavier University, Antigonish, Canada), Prof. J.I. Valenzuela-Ríos, (University of Valencia, Spain), Dr D. K. Loydell (Univ of Portsmouth, UK), Prof. P. Carls (Technical University Braunschweig, Germany), Prof. Liu Jin-yi (Chinese Academy of Sciences, China), Prof. A. Uchman (Jagiellonian University, Cracow, Poland), Dr. A. K. Rindsberg (University of Alabama, USA), Dr. A. V. Dronov (Geological Institute, Russian Academy of Sciences, Moscow, Russia), Dr. J. F. Genise (CONICET, Buenos Aires, Argentina), Prof. E. Luksevics (University of Riga, Latvia), Prof. J. W. Schneider (Technische Universität Bergakademie Freiberg, Germany), Dr. J. D. Gardner (Royal Tyrrell Museum of Palaeontology, Canada), Dr. J.-C. Rage (Muséum National d'Histoire Naturelle, France), Prof. Y. Wang (Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, China), Prof. H. Pffefferkorn (University of Pennsylvania, USA), Prof. J. Wang (Geology and Paleontology Institute, Nanjing, Chinese Academy of Sciences, China), Prof. B. A. Thomas (University of Aberyswyth, UK), Dr. A. F. Bannikov (Paleontological Institute, Russian Academy of Sciences, Moscow), Prof. Wiesław Krzemiński (Polish Academy of Sciences, Institute of Systematics and Evolution of Animals, Krakow), Dr. Harald Lobitzer (Geologische Bundesanstalt Wien, Austria). The cooperation with the above listed specialists resulted in many joint papers, most of them are listed in the text below.

During 2010–2014, the members of the Department participated in various international projects (e.g., UNESCO/IGCP projects and bilateral cooperations) and are authors and co-authors of a number of publication outputs (ca 84 papers in IF journals, ca. 60 papers in other journals, ca. 30 book chapters or books, and other publications). The members of the Department have been active in teaching, in popularization activities and, also, had important international duties (e.g., within the stratigraphic bodies of the ICS).

During the five-year period all the main research areas have also been successful in securing funding, and several long-term projects have been launched. The projects terminated in the period 2010–2014 can be listed as follows: IAA300130703 (GAAV ČR) Paleoecology, paleogeography, stratigraphy and climatic changes of the Upper Stephanian (Gzhelian) of the Central and Western Bohemian Basins; IAA301110701 (GAAV ČR) Reproductive organs and their spores from Carboniferous plants of North American coalfields; IAA304070701 (GAAV ČR) Cretaceous fossil flowers and inflorescences bearing pollen in situ; IAA301110908 (GAAV ČR) Dynamics of the Upper Ordovician climax-stage faunal

assemblages before global crisis controlled by climatic changes: a record from the Králův Dvůr Formation of the Barrandian area; GA205/09/0184 (GAČR) Small mammals at time of the middle Pliocene faunal turnover: aspects of faunal and phenotypic rearrangements in Central Europe; GA205/09/1521 (GA ČR) Feeding strategies in Cambrian to Middle Ordovician of the Teplá-Barrandian region; GA205/09/0619 (GA ČR) The Silurian Sedgwickii Event: Carbon isotope excursion, graptolite mass extinction, sedimentary record; GA205/09/0703 (GA ČR) Integrated late Silurian (Ludlow–Přídolí) stratigraphy of the Prague Synform. There are four ongoing projects that have been started in the last period: GA14-16124S (GA ČR) Refinement of lower Silurian chronostratigraphy: proposal of new GSSPs of the Aeronian and Homerian stages; GAP210/12/2053 (GA ČR) High-resolution floristic changes as a response to climatic dynamics during the Late Palaeozoic ice age recorded in the basins of the Bohemian Massif; GP13-19250P (GA ČR) Palaeobiological study of marine fossil fishes from the Oligocene of the Hermanowa locality (Poland) and M100131201 (International cooperation project of the CAS) Hi-res correlation and dating of Mid-Paleozoic sedimentary sequences of Peri-Gondwana using integrated biostratigraphy and chemo-physical methods.
Below, a sample of the most significant achievements is presented for each of the focal research areas.

Research Area 1 – Paleozoic biostratigraphy and paleoenvironment

The studies are focused on high-resolution biostratigraphy and relative dating of sedimentary rocks, development of biozonal scales, and complex biotic response to paleoenvironmental changes and global events using in particular graptolite and conodont faunas. (Projects: GA205/09/0703; IAA301110908; GA205/09/0619; on-going projects: GA14-16124S; M100131201).

One of the main sub-topics was the integrated stratigraphy of the late Silurian in the Prague Synform including the study of the global Lau Event as one of the most significant turnovers (paleoevents) in the Silurian, characterized by effects of various intensity on several fossil faunal groups. The event is accompanied by the strongest positive $\delta^{13}C$ isotope excursion in the entire Paleozoic. Accordingly, the information about this prominent geological Event contributes significantly to the understanding of palaeoenvironment and geochemical, climatic and palaeoecological impacts on sudden turnovers in biota in the fossil record. The Lau Event was characterized originally by a change in conodont faunas, partially during and after the *siluricus* Biozone. Accordingly, information about local conodont faunas is essential for direct documentation and evaluation of the Event in other regions and worldwide. Another issue was a comprehensive study on faunal and sedimentary changes and carbon isotope record across coeval middle Ludfordian Kozlowskii Event (graptolite extinction) as an example of our multi-proxy studies on Silurian global bioevents. Our data demonstrated the coincidence of the global crisis in pelagic conodonts and planktic graptolites with benthic faunal change and eustatic fall in sea-level manifested by facies change and the carbon isotope excursion. The study presents a novel refined graptolite and conodont biostratigraphy which is based on a continuous section and may serve as a template for global correlation of the Ludfordian Stage. The study was carried out in cooperation with Technical University Braunschweig and, the Czech Geological Survey (IDs 377156, 381838, 348542, 399225). Also, other biotic events/crises of the turbulent Silurian Period have been studied: e.g., the Leintwardinensis and Sedgwickii events, named after graptolite mass extinctions. The Gorstian-Ludfordian boundary was precisely located and defined using planktic graptolites. The Early Ludfordian Leintwardinensis Event was shown as a stepwise extinction of several prolific and morphologically distinct graptolite taxa rather than sudden collapse of the whole assemblage. Other fauna remained intact (ID 432545). The late Aeronian graptolite Sedgwickii Event, associated with positive carbon isotope excursion and facies changes in the Prague Synform, have been characterized in collaboration with the Czech Geological Survey (ID 381216). Late Ordovician-earliest Silurian environmental changes driven by vast glaciation on southern hemisphaere have been studied in collaboration with North American colleagues. Joint research commenced with a monographic study on taxonomy, biostratigraphy and faunal dynamics of the uppermost Ordovician graptolites from principal reference sections of north-central Nevada, including taxonomy, biostratigraphy and faunal dynamics which revealed a complex extinction pattern and ecological reorganization of the graptolite fauna across the Late Ordovician glacial period. Fossil assemblages have been analysed and interpreted in the context of Hirnantian mass extinction (ID 361335). A subsequent invited review on Late Ordovician-early Silurian environmental and biotic changes incorporated both existing and new data from around the world. A synthesis of sedimentary and fossil record, geochemical and stratigraphic data has shown that two phases of

Hirnantian mass extinction coincided with rapid climate-driven changes in oceanic anoxia, nutrient cycling and primary producer communities. The first phase coincided with the onset of glaciation and loss of anoxic conditions, the second phase occurred at the demise of glaciation followed by global O/S boundary anoxic event (ID 397852). The Ordovician–Silurian boundary in the Southern Alps, Austria has been identified using graptolites (ID 387246). Another two papers on Late Ordovician environmental changes and response of graptolite biota have been submitted in 2014.

There were other significant biostratigraphic studies that result in a better recognition of several stratigraphic intervals and biostratigraphic refinements: Revision of conodont biostratigraphy of the Wenlock–Ludlow boundary in the Prague Synform (ID 437691), development of regional Lochkovian conodont biozonation with global application (ID 382710), studies of Early Devonian conodont faunas in other areas, such as Urals (ID 393848) and Arctic regions (ID 429684) in collaboration with Russian and North American colleagues. Achieving the first successful reconstruction of the conodont apparatus from the Prague Synform, is particularly noteworthy for its stratigraphic importance for the substage boundary definition (ID 360806).

Ichnology (Project GA205/09/1521): Trace fossil assemblages may precisely determine a whole range of physical and chemical parameters of environment. In classical sequences of Devonian sedimentary rocks at the Onega Lake, trace fossils have been documented and interpreted in collaboration with paleontologists and sedimentologists from Baltic regions. They indicate that the whole Devonian rock complex in the study area originated in settings of a shallow sea (ID 0394257). Together with colleagues from Charles University, Praha (O. Fatka), ichnofossils associated with slightly skeletonized body fossils from Middle Cambrian of the Barrandian area have been presented. Some of the prominent and recurring features of the ichnofossils were interpreted as single-use traces of feeding on microbial halo (ID 386102). Trace fossils accompanying possible "Ediacaran organisms" in the Middle Cambrian sediments of the St. Petersburg Region, Russia have been described in cooperation with Russian colleagues. They document high-energy shallow water settings that might correspond with requirements of the surviving "Ediacaran organisms" (ID 340583). Trace fossil *Zoophycos* from the Cambrian of the Czech Republic proves the existence of complex helical burrows prior to the Great Ordovician Biodiversification Event (ID 439477).

Among other studies in the Paleozoic, the international collaborative research of Lower Devonian mudmounds of northern Spain resulted in the description of a new chambered hexactinellid sponge *Casearia devonica* (ID 437717). This unique fossil find represents the first evidence of chambered hexactinellid sponges from the Palaeozoic and the oldest representative of the order Hexactinosida in the world.

The results from the Paleozoic studies are considered as significant contributions to the IGCP/UNESCO Projects No. 591: The Early to Middle Palaeozoic Revolution, No. 596: Climate change and biodiversity patterns in the Mid-Palaeozoic and No. 580: Application of magnetic susceptibility as a paleoclimatic proxy on Paleozoic sedimentary rocks and characterization of the magnetic signal.

Research Area 2 – Carboniferous plants

Palynological and palaeobotanical research was focused on systematic positions of spores and plant taxa (IDs 424608, 429799, 399325, 394259, 376332, 376305, 342054) and palaeoecological intepretations of Carboniferous tropical forests (ID 432529). The team collaborated with several collagues from Czech institutions (National Museum, Charles University, Czech Geological Survey, West Bohemian Museum, Pilsen) and from UK, Germany, USA. A special type of collaboration was supported by the Czech and Chinese Academy of Sciences and by the University of Yunnan. The results are a part of project IAA301110701 and on-going project GAP210/12/2053.

The unit's research of the famous Ovčín locality near Rokycany, western Bohemia (ID 432529), where Pennsylvanian peat-forming vegetation is preserved in growth position, is of global importance. This vegetation has been studied in detail in the area of 12 hectares. Documentation of the fossil record in six new excavations and those previously collected in the former opencast mine allowed a detailed reconstruction of the local peat-forming lepidodendrid-cordaitalean forest structured into well-developed stories. It consists of about 33 species, which colonized the occasionally flooded planar peat swamp precursor of the Lower Radnice Coal. The canopy story of this vegetation was dominated by Lepidodendron, Lepidophloios and Cordaites taxa. They formed a relatively dense canopy, locally interrupted with significant gaps allowing development of a rich groundcover, that together with liana-

like plants, represents the most diverse part of the forest. A less diverse understory composed of calamites, medullosan pteridosperms and Psaronius tree ferns displays a patchy distribution pattern presumably related to density of the canopy. The minimal area that sufficiently represents the pattern of this forest phytocoenosis is estimated to be about 200 m^2, although lower stories are well represented even within much smaller areas of about 60 m^2. The fossil record of the Bělka tuff bed also indicates that the coal-forest colonizing the peat swamp was destroyed, presumably due to long-lasting flooding prior to the forest being wiped out by volcanic ash fall, and thus suggests that such catastrophic events were probably a relatively common part of the evolution of peat-forming Pennsylvanian successions.

Research Area 3 – Vertebrate Paleontology

The department includes a strong vertebrate paleontology team working on several faunal groups at different stratigraphic intervals.

(a) Mammals: These studies were focused particularly on refining taxonomic models in selected fossil mammal groups (Project GA205/09/0184), analyses of faunal rearrangements and their correlations with global palaeoenvironmental events. The main results can be grouped as follows. (1) Small mammal studies: A revision of the oldest modern Old World leporids (rabbits and hares) revealed that their spread throughout all Eurasia and Africa was very abrupt. This late Miocene event represents the important biotic marker, defined as "Leporid Datum" and is useful for Old World age correlations of sediments (ID 399112). Detailed analyses and/or revisions of Pliocene lagomorphs (genera *Prolagus*, *Ochotona*, *Trischizolagus* and *Pliopentalagus*) of Central and Eastern Europe (1) contributed to general understanding of environmental changes near the Miocene/Pliocene boundary, (2) enlarged knowledge of the early evolution of pikas and rabbits, and (3) provided an important tool for correlation of European Pliocene localities (IDs 342130, 391846, 354958). A new taxonomic model for the Pliocene Prolagidae of Central and Eastern Europe was proposed (ID 389602). A detailed revision of rodent genus *Micromys* was provided (ID 392565), finding that the European Late Miocene–Early Pleistocene record represents an independent evolutionary lineage, only distantly related to extant species. In collaboration with the National Academy of Sciences of Ukraine (Kiev) the rare Middle Pleistocene small mammalian fauna of Ukraine, important for reconstruction of the Pleistocene paleoenvironment, was described (ID 399136). (2) Large mammal studies: Revision of Late Gelasian to early Middle Pleistocene European ursids provided (1) evidence of two independent migration events of Asiatic black bear lineage (ID 376754), contrary to the previously proposed continuous occurrence of this lineage through the most of European Early Pleistocene, (2) evidence of the first unambiguous record of the brown bear in Europe and (3) better knowledge of cave bear dental apomorphies and early paleobehaviour (ID 382835).

(b) Frogs (Annurans): Paleobiological aspects dominated in studies on fossil frogs in the past five years in collaboration with several colleagues mostly from abroad, as seen in the co-authors of these publications. Basic data on anuran assemblages were gathered from various localities in Europe (Enspel, Late Oligocene, Germany; ID 348839), Asia (Shanwang, Middle Miocene, China; ID 365825; Liaoning Province, Early Cretaceous, China; ID 394766), and North America (late Cretaceous localities in Utah, USA; ID 348849; Green River Fm., Middle Eocene, Wyoming, USA; ID 436304). These served as a basis for re-assessments of dubious taxa (e.g., of the genera *Nezpercius*, ID 353605; *Eopelobates*, ID 436304; *Pliobatrachus*, ID 376336) and methodology (ID 388162), but principally for paleobiological interpretations, such as ontogenetic variation which is important for correct anatomical comparisons (IDs 383931, 365825, 354011, 354015), and for paleogeographical inferences (e.g., distributional dynamics of palaeobatrachid frogs between the late Cretaceous and middle Pleistocene, ID 376336; and explanations of pre-Eocene occurrence of the Pelobatidae in North America, ID 436304). The fossil record of Mesozoic and Tertiary anurans in Laurasia was summarized to indicate where further clarifications are needed (ID 399101). An attempt was also made to use anuran ilia, which belong among the most abundant osteological material in some late Cretaceous localities of Utah, for stratigraphic correlations. It turned out that developmental, individual, and species variation do not allow unequivocal conclusions based on poorly typological comparisons (ID 397850). Aspects of organ evolution in the anurans were studied on the ethmoidal region of the skull, the least affected by environmental adaptation (ID 348538), and on the locomotor apparatus of extant frogs (ID 434514).

(c) Fish: Fossil fish fauna has been studied in the different stratigraphic levels and regions. The previously described and/or evaluated Late Carboniferous and Early Permian non-marine fish taxa (sharks, actinopterygians, sarcopterygians) were used for diverse purposes (Project IAA300130703).

The fish palaeocommunities helped with stratigraphic problems during the geologic maping (IDs 425271, 425277, 425325, 353752, 353756, 423487), with the description of geologic units of the Bohemian Massif and its envelope (ID 345662) and with specifying the non-marine Carboniferous/Permian boundary (ID 382919). The reconstructions of the food-webs for the successive lake levels were important for evaluation of palaeoecological and palaeoclimatological changes and palaeogeographic development (IDs 398290, 439484, 432817). The above listed results represent contribution to the IGCP/UNESCO Project No. 575: Pennsylvanian terrestrial habitats and biotas of south-eastern Euramerica.

Modern teleosts (marginally elasmobranchs also) were studied at several Cenozoic sites representing different types of environments: Eocene and Oligocene marine fish of the Paratethys region has been studied from the systematic and palaeoecological perspectives (IDs 379855, 429542, 434044, 391320, 427682); general processes related with taphonomy (ID 371335); lepidological study of the fish material from the Eocene of Antarctica (Seymour Island; ID 386155); and description and interpretation of the Eocene and Oligocene fresh water fish fauna of North Bohemia (IDs 427683, 399102, 370446). In all results, members of the team studied fish specimens, prepared figures, main texts, and proceed to discussions of the results. Joint publications were prepared with several cooperating scientists from other Czech institutes (Charles University, Masaryk University, Technical University of Ostrava, Czech geological Survey, Municipal Museum Nová Paka, Museum of Eastern Bohemia in Hradec Králové) and with scientists from the USA (Dolan Integration Group), Russia (Russian academy of Sciences in Moscow), Poland (Polish Academy of Sciences in Krakow), and Romania (Natural Science Museum in Piatra Neamt). Many results represent the outputs of the ongoing project (GP13-19250P).

Research Area 4 – Cretaceous research

(a) Cretaceous microfossil biostratigraphy and paleoenvironment: Microfossil studies concentrated on palynomorphs (spores, pollen grains and non-calcareous dinoflagellate cysts), calpionellids and calcareous nannofossils. We focused especially on the biostratigraphy and paleoenvironmental changes of sedimentary rocks of the Lower and Upper Cretaceous of the Bohemian Cretaceous Basin, Outer Western Carpathians (Moravia) and coeval deposits in the Northern Calcareous Alps (Upper Austria), Slovakia and France. Integrated biostratigraphic and paleoecological analysis, using palynomorphs, foraminifers and calcareous nanoplankton, was carried out at several localities of the Outer Western Carpathians (Štramberk area, Tethyan province). Despite the fact that we cannot study a continuous section but only isolated exposures, microfossils documented two stratigraphic intervals of sedimentation: Valanginian–Hauterivian and Albian–Cenomanian. Depositional conditions varied from brackish and littoral to shallow neritic marine environments. The oxygen depletion zone was recorded in black shales of the Valanginian–Hauterivian age. The study presents a new insight into bioevents and documents sea-level changes. The study was carried out in cooperation with the Czech Geological Survey (L. Švábenická, L. Hradecká) and Technical University of Ostrava (P. Skupien) (IDs 365630, 353969). Other integrated biostratigraphic analyses were made using palynomorphs, foraminifers and calcareous nannofossils in the Turonian–Coniacian of the Gosau Formation in the Northern Calcareous Alps and resulted in several papers and mapsheet explanations (IDs 349919, 349929, 349931, 436070). Calcareous nannofossils confirmed Late Coniacian age and ammonite zones *Paratexanites serratomarginatus* and *Texanites pseudotexanus* in central and northwestern part of the Bohemian Cretaceous Basin. This project was carried out in cooperation with the Czech Geological Survey and Charles University, Faculty of Science (ID 0442216).

(b) Macrofauna, palaeoecology, sedimentary environments: Studies of sedimentary environment, faunal communities and palaeoecology were realized in the rocky-coast and nearshore facies of the Cenomanian–Turonian boundary interval in the Bohemian Cretaceous Basin. The first paper (ID 348551) has shown the directions and principal aims of investigations at Plaňany, which presently represents the most important locality. The first detailed paper (ID 437707) summarized studies of the Lower Turonian of Plaňany, mainly of new macrofaunal finds and the most important bivalves and sponges, palaeoecologic and taphonomic observations, origin and development of phosphatic accumulations and their constituents (faecal pellets, vertebrate coprolites etc.) including associated worm tubes (*Terebella phosphatica*) and other cementing epifauna of hard substrates. Crinoid studies (ID 437707) provided new, unique data on *Cyathidium* aff. *depressum* from the lower Turonian

of East Bohemia (Chrtníky), comprising investigations of growth (theca and brachials), encrusting fauna, taphonomy and palaeoecology.
This international collaboration focused on research of Upper Cretaceous invertebrate faunas from Germany – namely from Bavaria (ID 426424), Passau region (ID 375779) and Dresden area (ID 380035). Especially the studies of fossil sponges from these Cenomanian – Coniacian localities suggest their key role in the interpretation of palaeoecological conditions, such as the estimation of water depth and reconstruction of the sea floor substrates.

Other interdisciplinary topics

Among them, the discovery of a carved symbol on a waterlogged tree of the sixth–ninth century AD is noteworthy. It appears to be the earliest mark on a living tree that has so far come to light. The symbol was found "naturally buried" by a large irregularly-shaped piece of the outer, young wood that originated on a healed "scar". A search for such objects has never been undertaken before (ID 352850).

Long-term development of software applications for paleobiology, stratigraphy and sedimentology resulted in the completion of about 25 SW applications. Among them, e.g., part of the library of functions and SW programs for paleoecology (Go-eco library; ID 399347) that can be used, e.g., for taxonomic diversity estimates, and the library of functions and SW programs for chromatic adaptation (Chroma library; ID 399328) for colour characteristics of sedimentary strata.

All the above listed scientific results have been achieved in addition to service for the Universities (voluntary participation on the education), academic community (domestic and international), and many other activities listed in other parts of the evaluation documents. More importantly, these results can be also considered as a "by-product" besides the continually increasing "necessary" and "unnecessary" bureaucratic load and various non-productive paperwork tasks that negatively affect the scientific production of the entire Institute as all is being carried out mostly by the scientific staff. This, however, seems to be a general problem.

Research Report of the team in the period 2010–2014

Institute	Institute of Geology of the CAS, v. v. i.

Scientific team	Department of Environmental Geology and Geochemistry

The research team of the **Department of Environmental Geology and Geochemistry** has a relatively wide scientific scope covering several areas of geosciences. Thus the impact of achieved results is relatively broad as well, and it affects various national and international fields of social, cultural and economic life. Work efforts of the team in period 2010–2014 resulted in 71 papers in IF journals, contributions to more than 60 books/book chapters and more than 30 applied results, over 300 science popularization outputs and several conference proceedings. The most important results including selected IF papers and applied outputs were structured into 8 research areas in the following overview. They cover the processes in sandstone and karst areas, geomycology, dynamics of elements in the terrestrial/aquatic environments, recent pedological issues, research connected to repositories of radioactive waste materials, and development of analytical methods.

Research Area 1 – Processes in Sandstone Landforms

One of the important directions of research has been focused on the study of the so-called "sandstone phenomena", which is a framework of morphological features covering a wide range of sizes from macro- to micro-scales. Sandstone areas represent a common type of landscape in the Czech Republic but also in many other countries worldwide. Sandstones feature interesting landforms, usually being a subject of natural protection and conservation in numerous national parks (e.g., in the USA, Australia, China, Germany, UK, Czech Republic, etc.). National parks visited by millions of people each year have natural and economic importance for the society. Sandstone has been also important building material for millennia, therefore its weathering and erosion is a subject of high interest of people from application and scientific sphere. Although our team consists of chemists, mineralogist and geomorphologists, to achieve the complex results we co-operate with other internal or external teams (e.g., Brigham Young University, Utah; Charles University in Praha; Bohemian Switzerland National Park).

The research tasks focused especially on sandstone deterioration caused by natural or anthropogenic impacts. The results (IDs 382540, 382502, 362737, 392115) explain processes affecting and determining migration of mineralized fluids and subsequent precipitation of various salts on sandstone surfaces and in the near-surface zones. These processes strongly affect evolution of surficial sandstone cliff morphology and weathering rates. The research team is self-contained and covers all activities from periodical sampling, sample treatment and analyses, data interpretation, to publication of peer-reviewed papers. In the last years, we benefitted from enlargement of research team and contributed to tasks aimed at the understanding of the origin and development of various sandstone landforms.

Most importantly, we cooperated with Charles University in Praha. M. Filippi, within the research cooperation, provided mineralogical/chemical data and significantly contributed to the interpretation and publication of results. An outstanding output originated from this fruitful cooperation, explaining the formation of popular sandstone landforms such as arches and pillars (ID 432542). The presented principle, as evidenced by physical, numerical modelling and field observations, states that an increase in stress within a sandstone landform reduces erosion. This negative feedback, in combination with planar discontinuities in the rock, is sufficient to create these seemingly unstable landforms. This result induced high media response (e.g., Nature, New Scientists, BBC News, Scientific American, Smithsonian, Financial Times and tens of others).

Research Area 2 – Karst-Related Research

Geomorphology of karst areas in various soluble rocks (limestone, dolomite, salt, etc.) and related speleogenesis represents a traditional long-term topic of the Environmental Geology and Geochemistry team. The performed research is very complex, consisting of mineralogical, geochemical and geological approaches. The greatest part was conducted in carbonate karst of several European areas including an international co-operation with Slovenian, German, Romanian, Polish and Slovak research partners. Most studies from classical Slovenian and well-developed Slovak karst areas deal with detailed sedimentological and (micro-)paleontological analyses and geological dating leading to a better understanding of cave origin and related paleo-environmental interpretations (IDs 340565, 340578, 353334, 361336, 388179, 427465). A member of the team P. Bosák provided supervision onto the final interpretations and output production, and contributed to mineralogical and chemical data. Internal co-operation exists primarily with the Department of Paleomagnetism.

Research of karst areas represents one of the long-term aims of the team. But recently, the research activities spread into other directions – as demonstrated by studies dealing with the impact of floods along rivers (ID 379856) or by the evaluation of stratigraphically important Jurassic/Createous boundary (ID 353356).

The karst areas and caves became one of crucial sources of Quaternary continental climatic record during the last several decades. The use of speleothems for deciphering former climatic and environmental changes is well known. In the past several years, the team of the Department of Environmental Geology and Geochemistry focused on a new type of speleothem which forms during freezing of water in subsurface cavities – cryogenic cave carbonate. Coarse-grained cryogenic cave carbonate was defined as a new speleothem type and its formation processes were first explained in 2004 (K. Žák, V. Cílek and research participants from Poland). In 2010–2012, the team further expanded the study of these unusual cave carbonates, coining a new tool for the estimation of fossil permafrost depth penetration during the Quaternary glacials. The knowledge of former permafrost depths is important not only for the understanding of the paleoclimates, but also from technical and practical point of view – some rock types once subjected to freezing have different mechanical properties. The project had wide international co-operation with several universities, research institutions and museums in Germany, USA, Poland, Slovakia, Romania and Russia. The studied objects were located in several European countries. The study resulted in papers published in international journals (IDs 383497, 390419, 428067). Recently, several research teams in Germany, Spain and Russia further develop the study of cryogenic cave carbonates, which was first initiated by members of the Environmental Geology and Geochemistry Department.

A member of the team M. Filippi co-organized, and participated in, more than 10 geological expeditions to salt karst area in southwestern Iran. The long-term experience proved beneficial in the publication of two scientific papers in cooperation with colleagues from Charles University in Praha and Shiraz University, Iran (IDs 345509, 360816). First, the relatively complex study synthesizes various geological data from surface and caves of the Namakdan and Hormoz salt diapirs (Qeshm and Hormoz Islands, Persian Gulf). It presents a model of evolution and karst morphology in the Persian Gulf area during the last glacial cycle, based on effects of sea-level oscillation, diapir and regional uplift, and erosion. The second study (managed by member of our team) represents the most extensive review of halite chemogenic infillings found in the Iranian salt karst and also interprets the origin of these forms (ID 360816). Although the salt karst regions are rare, they occur in several continents (south America, Europe, Asia, partly Australia). There are only a few tightly aimed studies dealing with salt speleothems, therefore this paper (ID 360816) becomes a solitary source of extensive information for scientist dealing with salt speleothems.

Research Area 3 – Geomycology

Geomycology describes the role played by fungi in geological processes. The fundamental environmental importance of fungi involves organic and inorganic transformations and element cycling, rock and mineral transformations, bio-weathering, fungal-clay interactions, metal-fungal interactions, and mycogenic mineral formation. We mainly focus on the phenomenon of trace element accumulation in mushrooms (macrofungal fruit-bodies) and the environmental factors affecting the accumulation of elements.

Geomycology is an interdisciplinary science. Therefore, most of our studies are based on close co-operation with other teams. Through the intermediary of J. Borovička the team closely co-operates with the team at the Nuclear Physics Institute CAS who contribute the instrumental neutron activation analysis (INAA) – a suitable method for trace element determination in fungal tissues. Furthermore, we closely cooperate with the Laboratory of Fungal Biology at the Institute of Microbiology CAS where molecular methods (mainly DNA sequencing, community studies and qRT-PCR) are applied.

A complex study of the phenomenon of silver (Ag) accumulation in macrofungi was published in 2010 (ID 347030). Interaction of Ag with communities of soil saprotrophic organisms was studied in two different soils using a metagenomic approach (ID 434416). Organically bound Ag (biomass of Ag-accumulating *Amanita solitaria*) and mineral forms of Ag did not differ substantially in their effects on microbes in soil samples. The results indicate that soil microbiota can by significantly altered by decomposing Ag-rich fungal biomass.

Gold (Au) is another noble metal accumulated in macrofungi. A complex study of Au accumulation in macrofungi from an auriferous area was published by J. Borovička in 2010 (ID 334653). For the first time, gold concentrations were reported for ectomycorrhizal roots. The saprotrophic species *Lycoperdon perlatum* was found to be the most effective Au accumulator. The value of nearly 8 $mg.kg^{-1}$ Au (in dry mass) found is the highest Au concentration ever reported for a eukaryotic organism under natural conditions.

Suspicious results on uranium (U) content of macrofungi and interesting data obtained from fungal-uranium interactions *in vitro* prompted us to focus on the subject of uranium-thorium-rare earth elements (U-Th-REE) accumulation in macrofungi. Results from INAA were thoroughly compared with ICP-SF-MS in a more-or-less analytical paper published in 2011 (ID 364069). It appeared that the suspicious published data were erroneous due to application of inappropriate analytical method and due to sample contamination by soil particles. A complex study of U accumulation in macrofungi and ectomycorrhizae in U-polluted areas revealed that the accumulation of U, Th, Pb and Ag in macrofungal fruit-bodies apparently does not depend on total content and chemical fractionation of these metals in soils (ID 432829).

The possibility to use analytical method ICP-SF-MS prompted us to apply Pb isotopes in geomycological studies. As recently published, Pb isotopes can be used as tracers of soil origin of the accumulated elements (ID 428219), and further applications are planned for the future. Beyond this research, members of the team participated in three studies dealing with fungal ecology (IDs 350285, 373580), and one taxonomical paper on the genus *Psilocybe* was published (ID 360758).

Research Area 4 – Environmental geochemistry of potentially toxic elements

The environmental contamination with mercury (Hg) represents rather scarcely studied field of research in the Czech Republic. The most important historical sources of Hg in the central part of the Czech Republic were the mining and smelting activities near the Příbram Ore District. Records of temporal changes in historical contamination are important for future risk assessments. Changes in Hg emissions in the Příbram area were evaluated by means of tree ring study (ID 360810), which identified the maxima in 1970s, corresponding with a peak of regional metallurgical production. A more recent important source of Hg emissions has been the coal burning for public power generation and heating. The northwestern part of the Czech Republic, also known as the Black Triangle, was subjected to extreme levels of Hg deposition, which is well recorded in peat archives. Forest soils are an important storage of Hg from deposition but the information on pools and distribution of Hg in the Czech Republic were rather scarce. Comparative study of 5 sites inside and outside the Black Triangle area revealed that the local soil characteristics and properties are more important for the assessment of soil Hg contamination than the past level of deposition (ID 424916). Further migration of Hg from soils into surface waters occurs in connection with dissolved organic matter (ID 360811), which is important with respect to potential Hg methylation in anoxic environment and possibility for Hg to enter the food chain through fish. The study evaluated aspects of Hg export from forest catchment and its annual changes (ID 360811). Papers dealing with mercury contamination originated from projects led by the members of the Department of Environmental Geology and Geochemistry (M. Hojdová and T. Navrátil). The team members contributed by fieldwork, laboratory analyses, data interpretation and publication.

Within the problematics of element dynamics in the environment, we studied environmental contamination with potentially hazardous elements such as arsenic, mercury and thallium (IDs 334609,

432781, 337936, 436200, 377293, 377319, 391478, 392994, 432781, 360810, 360811, 424916). The spread of arsenic (As) contamination in the Czech Republic presents a potential threat especially in connection with the discovered but never mined gold deposits such as at Mokrsko, Czech Republic. The release of As from the natural geochemical anomaly represented by the Mokrsko gold deposit into surface stream waters studied by means of bio-film analysis (ID 432781) revealed that microbial activity and precipitation of realgar, secondary arsenic mineral, play a critical role. Microbial reduction promotes the release of As from Fe hydroxides and Fe arsenates (ID 392994). The transformation of arsenopyrite to scorodite by weathering was promoted in organic-rich soil layers of forested areas (ID 337936). Iron arsenates, especially scorodite, are the usual phases of choice for arsenic immobilization in waste. But the information on thermodynamic properties of scorodite and alike minerals was scarce, thus their solubility was determined by a series of experiments (ID 377319). Soils may act as an effective As sorbent: their capacity to attenuate spreading of As to the surrounding environment was determined at a former As mining site near Jáchymov (ID 377293). Members of the Department of Environmental Geology and Geochemistry team P. Drahota, M. Filippi and J. Rohovec contributed to the publications dealing with environmental aspects of As contamination by fieldwork, laboratory analyses and data interpretation.

Predominant anthropogenic sources of thallium (Tl) include emissions or solid wastes from coal combustion and ferrous and non-ferrous mining/smelting activities. But the general information on behaviour of Tl in soils was rather scarce. Soil properties such as cation exchange capacity and soil mineralogy were identified as the critical factors for the assessment of Tl behaviour in soil systems (ID 334609). Furthermore, we successfully tested the applicability of conventional extraction method (BCR) used for the assessment of iron speciation for the assessment of Tl speciation (ID 436200). The team members J. Rohovec and P. Drahota contributed to the research by analytical works and data interpretation.

Research Area 5 – Monitoring of Fluxes in the Environment

The monitoring of environmental fluxes and studies dealing with the dynamics of elements in the environment belongs to the main pillars of team activities. Besides the experimental site near Praha (ID 350910) operated by the team since 1990s, we conduct monitoring activities of the atmospheric deposition in cooperation with the Bohemian Switzerland National Park. The most significant result of this cooperation is the evidence of ongoing decrease of acidic deposition in the northwestern part of the Czech Republic known as the Black Triangle. This cooperation is annually reported by means of scientific reports (IDs 361399, 425727) and the results have been used as a base for scientific peer-reviewed papers (IDs 362737, 392115).

In terms of catchment monitoring related to dynamics of elements in the forested environment the team of the Department of Environmental Geology and Geochemistry has been co-operating with University of Maine, USA for more than 15 years. Outputs of this cooperation can be represented by papers assessing the climatic and seasonal aspects of stream export on paired experimental watersheds at Bear Brook (ID 348935). The major drivers of changes in stream chemistry were hydrology, vegetation activity and temperature (ID 348967). Team member T. Navrátil cooperated during his fellowship on the research by data analysis, equilibrium modelling and publication.

Solid atmospheric material – particles in the atmosphere – are of growing scientific importance due to their possible effects on natural and social phenomena such as weather, human health, precipitation events, transport etc. The role of natural dust is significant, even in the recent and present times which are characterized by extensive industrial, urbanization, rural-technological and traffic-related changes (ID 345506). In cooperation with the Department of Geological Processes, team members participated in research topics of particle identification and sampling by chemical analyses, data interpretation and paper publication. In the Czech Republic, we sampled, identified and quantified solid material from volcanic eruption in 2010 transported by atmospheric jet streams (ID 392114). This publication motivated research cooperation between the Institute and University of Iceland which resulted in another study of solid material transport in Iceland (ID 432640).

Research Area 6 – Pedology

A part of research has been focused on the study of pedological topics. Effects of different land use on the variability of the soil structure, soil hydraulic properties and different land use were studied on Haplic Luvisol, Greyic Phaeozem and Haplic Cambisol soil types (IDs 352619, 390422). The soil structure, aggregate stability and soil hydraulic properties were interrelated and dependent on variables such as vegetation cover and precipitation. The studies dealing with the quality of soil organic matter in the Czech Republic were rather scarce. Thus the efforts were aimed onto filling this gap by study of humic acid quality of Cambisols (ID 386578). Other studied field of soil research has been the effect of parent material on the intensity of specific pedogenic processes. The study of Bw horizon formation revealed possible differences among Cambisols developed on volcanic (ID 434627), paragneiss and granite bedrocks (ID 390445). The study of soil development on limestone bedrock (ID 424598) evaluated the most characteristic parent material for the Rendzic Leptosol. Finally, the team member A. Žigová contributed to the unification of the Czech scientific soil nomenclature (ID 424843) and its approximation to German and French classification systems.

Research Area 7 – Repositories of Radioactive Waste Materials

Disposal of high-level radioactive wastes into the geological formations is the worldwide-accepted concept of highly radioactive waste repositories. The migration of contaminants in the rock environment with the groundwater can be studied and modelled using various tracers. The team members cooperate with a consortium of private-owned companies (Isatech, Geomedia, Geotechnika) in this field since 2004. Fluorescent salts have been generally understood as valuable tracers for monitoring groundwater flow in fractured and porous environments. Team member J. Rohovec took a leading role in the development and testing of a utility model spectroscopic probe designed for monitoring of hydrogeological tracer movement in hydrogeological studies (ID 378823) with a possibility to quantify concentrations of the tracer in real-time reading. The applied research of non-active tracers continues through the project of the Technology Agency of the Czech Republic by a combination of laboratory and field migration tests accompanied by computer modelling (ID 427281).

The expertise of team members in the field of nuclear safety and other geochemistry-related areas has been demanded by state authorities such as the Ministry of the Environment and the State Office for Nuclear Safety. The accident at the Japanese Fukushima-Daiichi nuclear power plant in March 2011 (triggered by the earthquake and subsequent tsunami) induced international debate on the safety of nuclear energy usage. Countries operating the nuclear facilities have agreed to update the safety criteria for siting of nuclear facilities. In cooperation with other departments, the team members led a series of safety report reviews provided to the owner and operator of Czech nuclear power plant facilities (ID 368614, ID 422463). These individual review tasks were finalized by publishing a reports review and induced new field assessments using morphological, geophysical and geological methods (ID 368615).

Research Area 8 – Development and Innovation of Analytical methods

Due to the large proportion of analytical activities within the team of the Department of Environmental Geology and Geochemistry some results were dealing with comparison, improvement or development of analytical techniques. The team members provided the laboratory background, experiments, data interpretation and contributed to the paper publication.

Analysis of trace and ultra-trace amounts of sulphur in geological materials is a demanding task for optical emission ICP, but this technique is frequently the only possible. For this reason, we have developed and tested a new method for the determination of total sulphur in geological materials by optical emission ICP (ID 388152).

Isotopic ratios studies on ICP-MS generally require samples of excellent quality, low salinity and minute matrix effects. Routine application of the stable isotope determination of chromium in environmental and health protection research has led to the search for simpler chromite decomposition techniques. J. Rohovec participated in the development of a protocol for the decomposition of chromites based on oxidation by bromic acid at room temperature (ID 427709).

Project Summary

The funding of research yielding the above described results in the period of 2010–2014 was provided by several projects granted to the team members in the role of principal investigators by the Czech Science Foundation, the Grant Agency of the Czech Academy of Sciences, Ministry of the Environment CR and Ministry of Youth, Education and Sports CR. The most notable examples include project No. GA13-28040S Multi-approach study of processes in sandstone exposures: new view on study and interpretation of selected sandstone landforms, project No. GAP210/10/1760 *Cryogenic cave carbonates: Mechanisms of formation and relationship to permafrost depth*, project No. KJB315040801 *Salt karst in Zagros Mts., Iran: hydrogeology, dating and evolution*, project No. GAP210/11/1369 *The fate of legacy mercury in forest ecosystems in the area of the Black Triangle, Czech Republic*, etc. But the personnel of the Department of Environmental Geology and Geochemistry largely contributed to other research grants held by principal investigators from other departments across the whole Institute of Geology in roles of project team members.

Funding for the applied research projects originated from the Technology Agency CR, State Office for Nuclear Safety, Nature Conservation Agency of the Czech Republic, Bohemian Switzerland National Park and other institutions or private companies can be exemplified by project No. TA03021289 *Determination of migration parameters of rocks with fracture permeability using fluorescent solutions*, the contract project New interpretation of geological, geotechnical, hydrological and meteorological safety guidelines for site installations of new nuclear facilities (State Office for Nuclear Safety), the contract project Monitoring of the atmospheric deposition at the Bohemian Switzerland National Park (Bohemian Switzerland National Park Administration), contract project Evaluation of expected effect of Bílina mine on concentration of the fly dust in its vicinity (Severočeské doly, a. s. and Institute of Atmospheric Physics of the CAS), etc.

Research Report of the team in the period 2010–2014

Institute	Institute of Geology of the CAS, v. v. i.

Scientific team	Department of Analytical Methods, Geotechnics and Paleomagnetism

Research activities of the team cover a broad spectrum of topics. In addition to strictly scientific issues also service and counselling to the professional community, state, government or regional authorities, or business organizations are provided. Wide range of geoscience and material science disciplines covered by the members of the team resulted in production of 90 papers in journals with impact factor, 35 papers in peer-reviewed scientific journals, and over 10 chapters in books. Most of the research is carried out in a close cooperation with other teams from the Institute or those from other institutes of the CAS as well as foreign and domestic academic bodies (universities, research institutes). The most notable among them are: Faculty of Science of Charles University in Praha (E. Jelínek, D. Matějka, L. Strnad, M. Košťák, M. Mazuch, Z. Tasáryová, P. Kraft), Institute of Nuclear Physics of the CAS at Řež (J. Mizera, Z. Řanda), Institute of Physics of the CAS in Praha (J. Plášil), Institute of Inorganic Chemistry of the CAS at Řež (T. M. Grygar), Regional Centre of Advanced Technologies and Materials in Olomouc (J. Čuda, R. Zbořil), Department of Earth Sciences, University of Bristol (W.A.P. Wimbledon), Faculty of Natural Sciences, Comenius University, Bratislava (D. Reháková), Polish Geological Institute – National Research Institute, Warsaw (J. Grabowski), University of Granada, Faculty of Sciences (F. Olóriz Sáez), Institute of Geophysics (V. Vavryčuk), Joint Institute for Nuclear Research in Dubna (A.N. Nikitin, T.I. Ivankina, R. Vasin), Institute of Geosciences, University of Kiel (H. Kern), Department of Earth and Planetary Science, University of California, Berkeley (H.R. Wenk).

Research Area 1 – Paleomagnetic and rock magnetic investigation of the Prague Basin

Multidisciplinary investigations were carried out on samples from various localities around the Prague Basin. A new paleomagnetic database with information of paleomeridians, paleolatitudes, paleorotations, and the approximate ages was established. Paleomagnetic and paleogeographic investigations of five Silurian localities (Kosov Quarry section, Černidla, Třebáň, Vinařice, Vyskočilka) showed that paleomagnetic pole positions fit well with the theoretical model paths simulating the distribution of pole positions due to horizontal paleotectonic rotations. The mean paleolatitude of 22.5° ± 6.6° calculated from all localities positioned on the southern hemisphere was computed for the Silurian. These investigations support the opinion that the Prague Basin was a continental rift basin, situated on the presumed Perunica Microplate which drifted at southern subtropical paleolatitudes of 24° in the Late Silurian times, and experienced either a 170° counter-clockwise, or a 190° clockwise rotation during the Variscan Orogeny. Paleomagnetic data for the Lištice area are, however, different than those for the above mentioned areas and prove a relatively strong remagnetization in the Late Carboniferous–Early Permian with no significant rotation.

The rock magnetic investigations of Lištice, Černidla and Kosov show the presence of Ti-magnetite, goethite and traces of hematite, with no significant frequency dependence and only minor amount of superparamagnetic particles. The Ti-magnetite within amygdales of Lištice samples was found to be carrying the characteristic remanent magnetization and reflects probably the Permo-Carboniferous remagnetization of volcanic phases. The sedimentary petrology studies of the Silurian concretions (Kosov) support the rock magnetic and magnetomineralogical data. The XRD analyses were indicative of the different compositions of the concretions and show great difference between the levels with concretion formations. The mineral composition was shown to be significantly affected by early diagenetic changes. Additionally, the investigations of the telescoping of tiny and narrow, hollow conical shells show that an extremely high telescoping effectiveness in highly turbulent flow with rapidly stirred mud was prevalent and is comparable to the conditions at the front and shear zones of mud-laden turbidity currents cannibalizing the mud on the seafloor.

In this topic, the team participated (60 %) in sampling, performed measurements, and interpreted and published the results (IDs 367129; 334641; 340715, 345505, 346371, 368273, 376517, 381768, 382559, 389165, 397115, 429926, 432989, 434872, 423376, 437534, 398465).

Research Area 2 – Paleomagnetism and magnetostratigraphy of Cenozoic cave sediments in Central Europe

To obtain magnetostratigraphic data we investigated paleomagnetic properties of autochthonous and allochthonous cave sediments at 48 profile sites in different geomorphological positions in the Carpathians, Dinaric and Alpine karsts. The sediments, spanning the age from the latest Quaternary to at least the Pliocene also exhibit measurable and statistically significant paleomagnetic declinations, inclinations and polarity. Measured declinations reach up to 18^o with α in the range of 3 to 6^o on the average. Rotations are predominately CCW in sense, consistent with the CCW-rotating Adriatic microplate. The first group exhibits rotation rates of ca. 1^o/Ma, probably indicating a movement of these sites with the Adriatic microplate. Sites from the second group show rotation rates of around 5^o/Ma and could be influenced by local tectonic block rotations in active fault zones since the faster rotation rates are viable with respect to active regional deformation rates derived from the GPS studies. Our work demonstrates that it is possible to acquire meaningful paleomagnetic declination data from highly discontinuous and fragmentary continental sedimentary record preserved in karstic caves, and magnetostratigraphy of cave sediments seems to be an ideal tool for dating. Nevertheless, our practical experience with sampling, construction and interpretation of magnetostratigraphic profiles has also shown the presence of substantial problems with the stratigraphy of cave fills, erosion features, available paleontology, etc.

In this topic, the team participated (60 %) in sampling, performed measurements, and interpreted and published the results (IDs 366685, 380024, 382841, 394965, 394968, 394978, 361401, 361402, 366778, 382140, 432964, 427465, 340565, 340578, 353334, 345032, 345524, 345525, 371402, 374111, 386117, 386138, 399071).

Research Area 3 – Laboratory investigations and simulations of extraterrestrial materials

The research focused on three main topics: (1) Low-temperature magnetic properties of the iron-bearing sulphides in extraterrestrial materials (team contribution 50 %); (2) space weathering laboratory simulations (60 %), and (3) the study of physical properties and reflectance spectra of meteorites and micrometeorites (60 %).

A series of low-temperature magnetic measurements were performed with troilite (FeS) and alabandite (MnS) minerals to study the magnetic properties at temperatures of the cold interplanetary environment. The study confirmed that troilites undergo a magnetic transition at ~70 K from the high-temperature antiferromagnetic regime to the low-temperature ordered magnetic state exhibiting higher magnetization. On the contrary, the existence of a similar transition reported previously by other research groups in alabandite was disproved and attributed to surface oxidation/contamination.

In order to get insights into the natural space weathering process the optical effects of asteroid surface space weathering associated with micrometeorite bombardment and related occurrence of nanosized metallic iron (npFe0) were studied. It was discovered that space weathering-related production of npFe0 proceeds linearly with time, while associated spectral changes evolve logarithmically with time. This can explain the observed rapid onset of space weathering of fresh planetary surfaces. As the material becomes more mature, spectral changes become slower.

The studies of meteorites focused on three areas – Almahata Sitta meteorites, Chelyabinsk meteorites, and micrometeorites. Asteroid 2008 TC3 was the first asteroid detected in space prior to its impact with the Earth (2008). The subsequent study of the associated Almahata Sitta meteorites showed that the asteroid 2008 TC3 was a heterogeneous rubble pile and may have been lighter and more porous than previously thought. Study of the Chelyabinsk meteorites revealed that some meteorites are darker and contain crushed and melted mineral grains. Such shock-darkening was caused by ancient space collision of their source asteroid with another body and may explain the origin of some dark asteroids observed in our Solar System. Through non-destructive X-ray studies it was possible to determine the density, porosity, mineralogy, and internal structure of cosmic dust recovered in the form of micrometeorites. The results indicate that at low entry velocities no significant changes are observed. In contrast, at high entry velocities partial melting with significant porosity increase occurs followed by

complete melting, metal segregation, and reduction in pore space (IDs 383519, 367270, 386420, 346467, 353782, 367277, 368857, 383522, 397111, 427675, 427677, 427679, 429763, 430060, 430065, 345028, 399259).

Research Area 4 – Magnetic scanning of volcanic rocks and multidisciplinary international studies

The team utilized a magnetic scanner for the interpretation of paleomagnetic signal of volcanic rocks. Magnetic scanner proved to be a vital tool when interpreting the paleomagnetic information from the Lištice and Černidla basaltic lava flows. Three different magnetic textures were seen and, in combination with optical imaging, related to petrological features which helped to constrain the overall geological interpretation.

Additionally, the team was involved (20 %) in several international research topics such as: (1) Magnetocaloric materials and NIST experience with Gd-alloys; (2) effects of high magnetic fields on various types of biological cells; (3) sandstone landforms and the parameters controlling their shapes; (4) microspherules and identification of a new type of proxy for climate change research; (5) Younger Dryas Boundary in the North and Central America, Near East part of Asia, and Western Europe; (6) space weathering; (7) moving rocks in the Death Valley; (8) temperature changes in the lake due to tides, and (9) magnetic minerals attracted to permanent magnet on board of Mars rovers Opportunity and Spirit (IDs 375446, 367128, 360975, 378869, 393036, 396252, 361410, 398581, 424776, 424820, 432542, 432983).

Research Area 5 – Landslide history recorded in a floodplain natural archive

Landslides represent serious geohazard features. A detailed study of the sedimentary archive within a landslide-controlled floodplain (Smrdutá site, Czech Flysch Carpathians) revealed a local mass wasting history controlled by climatic and geological settings based on sedimentological, pollen, magnetomineralogical and geochronological evidence. A sedimentary sequence deposited behind a landslide dam points to two highly discontinuous depositional events dated to 4.6 and 2.0 cal. ka BP, whereas the last cycle started approximately in the 17–18th centuries and has continued to recent times. Such sedimentary pulses characterized by duration of several decades to a few centuries originated as a consequence of the blockage and/or reduction of the valley floor width by successive landslides. Stages of mass wasting activity correlate well with major, humid late Holocene climatic oscillations suggesting its high sensitivity to century-scale climatic deteriorations. The character of sedimentary traces caused by the July 1997 extreme flood indicates a decisive role of large flood events during erosion and accretion of the floodplain sedimentary sequences.

In this topic, the team participated (50 %) in measurements and interpretation of data and worked on writing the publications (IDs 345542, 356705, 391840, 372976, 365627, 377902, 389162, 424766, 345007, 345014, 345523, 352793, 361386, 361407, 377342, 377349, 388375, 398333, 434146, 345037, 381331, 389145, 422176.

Research Area 6 – Magnetostratigraphy of the Jurassic/Cretaceous boundary strata in the Tethyan and sub-Boreal Realms

The definition of the Jurassic/Cretaceous (J/K) boundary has not been established yet, which makes it the last system boundary without a GSSP. The base of the Berriasian Stage, i.e., of the Cretaceous System, is assigned in the Geologic Time Scale (GTS) 2012 to the base of Magnetochron 18r, which has an age of 145.0 Ma. On several pilot localities (e.g., Puerto Escaño – Spain; Nutzhof – Austria; Le Chouet – France), we successfully applied the high-resolution magnetostratigraphy and determined individual magnetozones and subzones and we correlated the profiles. Paleomagnetic and petromagnetic analyses from key intervals precisely determined the boundaries of two reverse magnetozones (M18r, M19r) and the "Kysuca Subzone" M20n.1r. The results of additional pilot samples from: Štramberk, Kurovice – Czech Republic, Strapková – Slovakia, Durlston Bay – England, St Bertrand's Spring – France are objectives for new proposal for the Czech Science Foundation. International Commission on Stratigraphy (Subcommission on Cretaceous) submitted the new proposal of fixing the J/K boundary based on our results. The base of M18r reverse polarized zone (M18r/M19n interval) was selected as the principal correlation event. The team participates in international collaboration with the Berriasian Working Group. In this topic our team prepared and processed the

samples, conducted measurements, carried out interpretation and wrote scientific publications (IDs 429603, 338934, 349405, 353356, 360935, 378776, 392582, 424593, 428331, 434688).

Research Area 7 – Elastic and mechanic properties of rocks – anisotropy, crack distribution, acoustic emission (AE)

Anisotropy of rock belongs among basic material properties. Rock mass can behave anisotropic due to several reasons and what is important anisotropy can be influenced by physical or chemical conditions acting in a rock massive. Analysis performed on spherical sample can provide 3D information of elastic properties on studied rock samples. In this area, the team is responsible for sample preparation, measurement in a high-pressure apparatus up to 400 MPa by P and S waves, data analysis and interpretation. The high-pressure apparatus designated for measuring spherical samples is, for its uniqueness, demanded by domestic as well as foreign research groups. It is always very interesting to apply methods that are commonly used on samples of other shapes and apply them on the sphere. Technical solution of the new measuring head was submitted to Industrial Property office as PV2014-785 to apply for patent granting. Description of rock failure process is equally important, especially for applications in practice. During the 2010–2014 period, the collaborative studies on rock elastic anisotropy with institutions from the Czech Republic and abroad (Australia, Germany, India, Russia, USA) resulted in 14 papers in IF journals. Most of the work was performed in laboratory conditions, only four papers were accompanied with *in situ* measurements. The above mentioned four papers were focused on scale study under field and laboratory conditions. There was made a comparison of elastic (P and S) wave transmission, velocity anisotropy, influence on crack distribution and velocity dispersion. All authors are members of the Institute team. Collaborations with foreign researchers always have a few things in common. The Institute team was always responsible for sample preparation (sphere or cylinder), measuring, data analyses and interpretation. Our partners then usually provide material of their interest and, if necessary, other investigation methods. The study of stress-dependent seismic anisotropy of the overburden shale in an oil field in the North West Shelf of Western Australia by ultrasonic sounding by P waves up to 400 MPa determined an orientation of the symmetry axis and discovered a different behaviour at lower and higher pressures. Two papers studied the influence of thermal heating on elastic anisotropy of granulite. Our Indian partners realized SEM analyses. It was found that repeated heating and cooling of the granulite spherical specimen leads to fast crack closing at low pressures with no *a priori* relation to orientation of primary microcracks systems. Other four papers are aimed at experimental and theoretical study of elastic wave field pattern in anisotropic texturized rocks. Collaboration with Russian partners focuses on the experimental verification of the theoretical calculations. The characteristics of the wave fields observed during the transmission of quasi longitudinal ultrasonic waves through polycrystalline graphite samples have been studied. The specific features of propagation of elastic waves in a bilayer medium, where one of the layers (isotropic) is an acrylic glass hemisphere and the other (anisotropic) is a polycrystalline porous graphite hemisphere, are considered. The experimental results were compared with theoretical calculations using data on graphite crystallographic texture obtained previously by neutron diffraction on SKAT texture diffractometer at the reactor IBR-2 at JINR, Dubna, Russia. It was shown that the anisotropy of the elastic properties of reactor graphite GR-280 is due to the crystallographic texture formed during the extrusion process, but the internal pores and microcracks are not closed even at a pressure of 150 MPa and they greatly influence the exact values of the bulk elastic moduli of graphite. Samples from a deep Outokumpu drillhole, Finland, were examined in two other works. This material is well-known, thus it was very good to confirm our new methodology of measuring shear (S1 and S2) waves on spherical samples at hydrostatic pressures up to 100 MPa. In collaboration with V. Vavryčuk from the Institute of Geophysics of the CAS, we described a new method of calculation of full elastic tensor. This method is based on an inversion of phase and ray velocities of P, S1 and S2 waves, and its robustness is demonstrated by results of a synthetic test. V. Vavryčuk took care of the theoretical part of work – calculation process and its description in the text; we provided measurements, synthetic tests and data analysis of P-, S1- and S2-wave velocities. Finally, we compared our results from ultrasonic measurements on a sphere with those performed by neutron diffraction at the JINR by Dr. Ivankina. In addition, velocities measured on sample sphere were compared with those obtained on a cube that was prepared from the same core segment. Measurement on a cube was taken by Prof. Kern from Kiel. In many practical applications, it is very important to know the process of rock failure. One work of our team was focused on this topic. We use

an acoustic emission as a tool for monitoring process of rock failure during uniaxial loading. Multiple transducers are used both to monitor acoustic emission and to measure velocities in different propagation directions. A sparse network of transducers located on the rock core surface allows approximation of elastic waves velocity distribution as an ellipsoidal surface. The shape and orientation of the velocity ellipsoid is a measure of velocity anisotropy. A study of changes in velocity anisotropy and its orientation was performed on uniaxially loaded migmatite rock samples with a distinct foliation. Orientation of the velocity ellipsoid corresponded to the anisotropy of rock structure up to the activation of a failure plane. Prior to brittle failure, the axis of minimum velocity rotated from its initial direction normal to the foliation to a direction normal to the failure surface. The use of time-variable ellipsoidal velocity model led to a better localization of acoustic emission events during the sample loading when compared to the use of time-variable isotropic velocity model. The position of the failure plane determined by clustering of acoustic events foci coincided closely with the observed sample failure. Afterwards, this method was applied in collaboration with Indian partners (IDs 348544, 360814, 379243, 392585, 363147, 382046, 379244, 363144, 379246, 381226, 387238, 429000, 433696, 390540).

Research Area 8 – Investigation of quartz deformation affecting the ASR in concrete – a **quantitative analysis of quartz deformation affecting the ASR in concrete**

The project is aimed at: (1) aggregate sampling; (2) laboratory preparation and analysis of ASR of aggregates employing accelerated mortar bar test; (3) modification of seismoacoustic emission monitoring under special experiment conditions; and (4) development of high-temperature AE transducers and complete monitoring system.

Semi-continuous ultrasonic sounding of experimental mortar bars used in the accelerated alkali silica reactivity laboratory test (ASTM C1260) is proposed as a supplementary measurement technique providing data that are highly sensitive to minor changes in the microstructure of hardening/deteriorating concrete mixture. A newly designed heating chamber was constructed allowing ultrasonic sounding of mortar bars stored in an accelerating solution without the need to remove the test specimens from the bath during the measurement. Subsequent automatic data analysis of recorded ultrasonic signals proved their good correlation with the measured length changes (expansion) and their high sensitivity to microstructural changes. To confirm ultrasonic results, expansion test and SEM/EDS examination of ASR-related damage were carried out. It was found that high-reactivity aggregates pronounced by high mortar bar dilatancy result in a significant decrease in P-wave velocity and high ultrasonic signal attenuation. Acoustic emission can be used for ASR study mainly during first days of ASTM C1260 study to monitor the origin of the ASR. Ultrasonic sounding and acoustic emission monitoring can be used as effective supplementary tools for the monitoring of internal structure of expanding mortar bars during laboratory tests for the evaluation of alkali silica potential of aggregates. Heating chamber modification, sensor protection testing, ultrasonic sounding and acoustic emission monitoring with data interpretation were done by the Institute team. New technical approach of the ASR monitoring based on ultrasonic testing is prepared to be submitted the application form to Industrial property office for patent granting. One manuscript has been submitted to an IF journal for publication (Semi-continuous ultrasonic sounding and changes of ultrasonic signal characteristics as a sensitive tool for the evaluation of ongoing microstructural changes of experimental mortar bars tested for their ASR potential, IDs 382046, 390540, 429000, 433696).

Research Area 9 – Effects of long-term natural irradiation on minerals

A detailed study of minerals and their associations subjected to prolonged irradiation can provide valuable information on behavior of rocks under such conditions and consequently may be useful for nuclear waste management.

Effects of strongly radioactive primary minerals (mainly monazite) on the surroundings are compared in granites and paragneisses of the Moldanubian region in the Bohemian Massif. Aureoles of secondary phases extend up to 20 mm from the monazite surface. They mainly consist of low temperature clay minerals usually mixed with Fe-hydroxides. The frequent association of monazite with hydrated secondary phases may contribute significantly to resetting monazite ages during metamorphism and partial melting. The team member (Z. Korbelová) provided a complete chemical characterization of the samples on the microscale (ID 368278).

Fluorite and substances with fluorite-based structures have been repeatedly expected to represent materials suitable for nuclear waste management based on studies on experimentally irradiated samples. However, sole application of radiation doses cannot account for time factor. Therefore, samples of fluorite that underwent a natural irradiation lasting millions of years have been selected for the investigation. Fluorites were irradiated by either uraninite or allanite. All samples were studied by several analytical methods, including X-ray diffraction, positron annihilation spectroscopy, photoluminescence spectroscopy and transmission electron microscopy. X-ray powder diffraction indicates the presence of peak broadening which mostly due to micro-strain contribution whereas domain size induced broadening is negligible. The degree of peak broadening is proportional to the expected irradiation dose. Transmission electron microscopy (TEM), similar to X-ray diffraction, showed that defect concentration depends on the radiation source activity. The reference material displays no defects observable by TEM whereas, dislocation loops occur in the sample experiencing low irradiation, and the highly irradiated sample contains such high density of defects that it makes it almost impossible to distinguish individual dislocations or dislocation loops. Next to the dislocations and dislocation loops, calcium inclusions are present in the sample which underwent the most severe irradiation but absent in low-irradiated or standard samples. Spectroscopic methods and calculations helped to characterize the defects on an atomic scale. Irradiation is responsible for the formation of vacancies and their agglomeration. All the observations above make the use of fluorite as prospective containment of radioactive waste rather questionable. A team member (R. Skála) contributed to selection of methods of the research as well as formulation of the results (IDs 357908, 377454).

Secondary uranium minerals can be used as models of behavior of nuclear uranium-bearing material under diverse thermodynamic or kinetic conditions. The collection of paper focused on several such minerals (grimselite, leydetite and agricolaite) presents a complex structural and chemical study of uranyl minerals. Team members (A. Kallistová and R. Skála) were involved mainly in powder diffraction and microprobe characterization of the materials (IDs 368288, 397410, 379239).

Research Area 10 – Moldavites and other tektites and impact glasses: composition, properties and origin

Lithium abundances and isotope compositions were determined in tektites (including moldavites), selected impact-related glasses and glass fragment from the suevite from the Ries impact crater as well as possible source sedimentary materials in order to test a possible susceptibility of Li to fractionation during hypervelocity impact events. A set of samples was selected based on the major element compositions determined by a member of the team (R. Skála). Generally, data show a large spread in Li abundance as well as isotope composition but the values for a particular group of glasses are always similar. The results show that any significant high-temperature Li isotope fractionation can be excluded by comparing moldavites with sedimentary lithologies from central Europe (in principle their expected source materials). Instead, the Li isotope compositions in tektites and impact-related glasses are probably diagnostic of the precursor materials and their pre-impact geological histories (ID 363169).

A part of the team was involved (macroscopic, microscopic and chemical characterization of samples, R. Skála and his PhD student, participation 15 %) in the study of porosity in moldavites through X-ray micro-computer aided tomography (μ-CT) combined with optical microscopy and imaging. These techniques enabled a complete characterization of the textural features of both Muong Nong-type and common splashform moldavites. A detailed study of the size and distribution of pores or bubbles confirmed a marked variability in pore size among the samples, as well as within each sample, and indicated the presence of at least two deformation stages in the Muong Nong-type moldavites, which occurred before and after pore formation (ID 432917).

To clarify the problem of carbon content and carbon isotopic composition of the tektite glass, three samples from the Central European tektite strewn field – moldavites – were analysed. This research demonstrates the co-operation of individual teams within the Institute. Resulting publication belongs to a series of papers focused on moldavites and tektites in general. The study revealed that the samples contained only ~30 to 40 ppm C. Isotopic C composition identified terrestrial organic matter as a dominant carbon source during moldavite formation (ID 378775).

Research Area 11 – Characteristics of the crystallization history of rocks of the Roztoky Intrusive Complex, Ohře/Eger Rift (České stredohoří Mts.)

The Ohře Graben (OR) contains, in addition to volcanic rocks, hypabyssal rocks of the high-level intrusions. The largest center of magmatic activity of the České středohoří is the Roztoky Intrusive Complex (RIC). Hypabyssal intrusions occur in a close proximity to the centre. Information on the hypabyssal rocks is limited although they can provide constraints on the genesis of the subvolcanic level of volcanism and refine the ideas on the rift history. The goal of the project was to constrain the petrogenesis of the the Roztoky Intrusive Complex. The variations in major elements, petrographical characteristics and mineral chemistry indicate that the RIC suite, including hypabyssal rocks of intrusions and both dyke series were derived by fractional crystallization and assimilation-fractional crystallization accompanied by the late magmatic transfer of volatile fluids. These fluids could be derived from a metasomatized mantle source such as the subcontinental lithospheric mantle beneath the Bohemian Massif sampled by metasomatized mantle xenoliths (ID 399310).

Research Area 12 – Phase relations and crystallography of synthetic phases in selected binary and ternary systems involving transition metals and chalcogenides

Phase relations within the Fe-Nb-S system were studied in the temperature interval 400–1000 °C. The dominant field in the system is a broad solid-solution $Fe_xNb_yS_2$ ($0 < x < 0.5$, $1.0 < y < 1.4$) that includes the composition of the mineral edgarite. Also, it forms stable assemblages with pyrrhotite and pyrite. The iron sulphides dissolve limited amounts of Nb: pyrrhotite dissolves up to 1.13 at. % Nb, and pyrite, only 0.02 at. % Nb. Phase relations in the Re-Mo-S system were studied in the temperature range of 400–1200 °C. Experiments showed an asymmetrical behaviour of the MoS_2-ReS_2 solid state solubility: molybdenite dissolves 2.7 wt, % Re at 1000 °C, 2.6 wt. % Re at 800 °C, and 2.2 wt. % Re at 400 °C, whereas ReS_2 shows negligible Mo contents at all temperatures. The experimental solubility of ReS_2 in MoS_2 far exceeds Re contents in natural molybdenite. The 400 °C isothermal section was studied for the Ni–Sb–Te system. Two extensive ternary solid-solutions were detected in the system, λ_1, $Ni(Sb_{1-x}Te_x)_{1+y}$ ($0 < x < 1$, where, for $x \geq 0.9$, the relation $0.09 \leq y \leq 1$ applies), and λ_2, $NiSb_{1-x}Te_{2x}$ ($0.28 < x < 0.66$). These two solid solutions are breakdown products of the broad NiSb–NiTe–$NiTe_2$ solid solution that dominates the system at temperatures higher than 690 °C. The mineral vavřínite, Ni_2SbTe_2, is a part of the λ_2 solid solution at 400 °C. The team members (V. Böhmová, R. Skála) contributed to chemical composition and crystal structure characterization of the involved phases and their assemblages. Contribution of the team to the research is between 20–40 % (IDs 356123, 350012, 350042).

Research Area 13 – New mineral descriptions

Team members (R. Skála, A. Kallistová) also actively participate in the new mineral descriptions. Kitagohaite represents an ordered phase within the system Pt-Cu. The mineral has a synthetic analogue and thus its occurrence constrains the temperature under which the association of minerals with kitagohaite may have formed. Although the mineral is associated with other Pt-rich minerals occurring otherwise in high temperatures, in this case the temperature did not exceed 500 °C. Supergene minerals may well constrain the physical and chemical conditions in various environments and help to understand even complex processes operating, e.g., in mine waste dumps. Two new minerals, agricolaite and švenekite, represent such secondary phases. Agricolaite is a potassium uranyl carbonate with ideal formula $K_4(UO_2)(CO_3)_3$. The mineral was thoroughly characterized by chemical and crystallographic data. Švenekite is a triclinic arsenate of ideal formula $Ca[AsO_2(OH)_2]_2$ found in the Jáchymov ore district. The paper provides all properties characterizing the mineral including morphological, chemical and structural data. Another newly discovered mineral of secondary origin is leydetite. It is a monoclinic uranyl sulphate of ideal chemical formula $Fe(UO_2)(SO_4)_2(H_2O)_{11}$. It was found at the locality of Mas d'Alary, Lodève, Hérault, France (IDs 397450, 432914, 397410, 368288).

Research Area 14 – Analytical service for research projects

Electron probe microanalyses were collected as a service to cover analytical needs of following scientific projects: IAA300130612; IAAX00020702; IAA300130801; IAA300130902; KJB300130902; 14-13600S; 210/10/1105; 205/09/1170; 202/09/1206; 210/10/1309; 210/10/1309; 205/09/0991; 210/11/1369; 13-15390S; 13-22351S; 13-28040S; LH12079; M100130902; M100130904;

M100130904; AVOZ30130516; AVOZ30130516; AVOZ30130516; AVOZ30130516. Special routines and/or analytical protocols have to be developed in some cases requiring a deep integration of team members to research groups (IDs 346334, 397111, 430060, 430065).

Besides chemical composition, electron microscope imaging has been required for a successful completion of project IAA301110908; 14-18183S; P210/12/2053; 205/09/0184; 205/09/1521; 205/09/0619; 205/09/0703; 13-19250P; 13-13967S; M100130904; AVOZ30130516; AVOZ30130516; AVOZ30130516 and in certain cases it was crucial for the research goals (IDs 359012, 376086).

X-ray powder diffraction helped to solve an analytical enigma associated with electron probe microanalysis of finely intergrown lamellar aggregates of pyroxene and leucite demonstrating the necessity to combine multiple analytical techniques in complicated samples (ID 377489). Other important use of XRD was the study of volcanic ash particulate matter from the 2010 Eyjafjallajökull eruption (ID 392114) and suspended dust deposition during moist and low wind conditions in Iceland (ID 432640).