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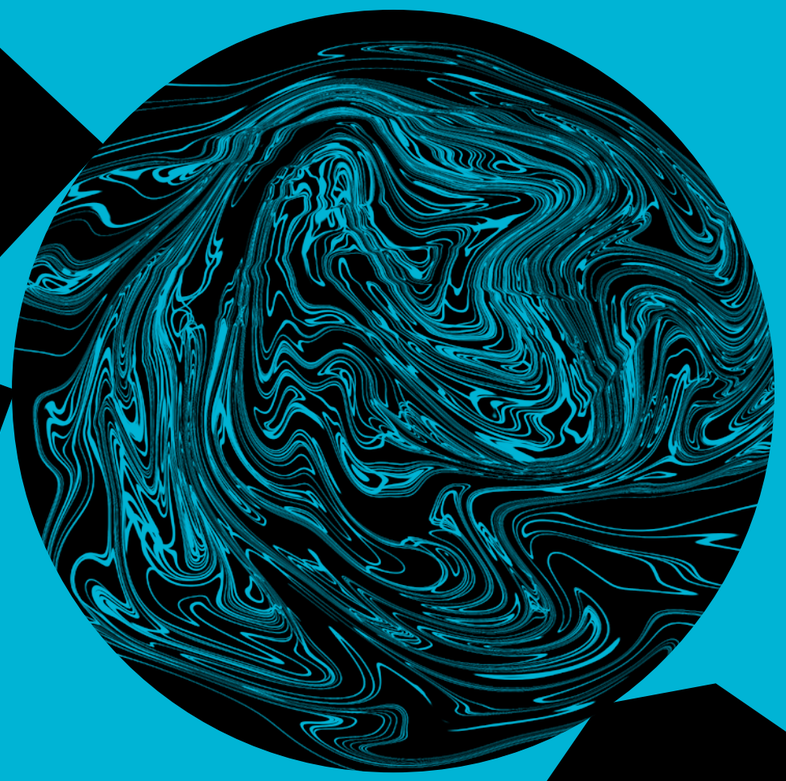
ISOTOPE CLIMATOLOGY AND ENVIRONMENTAL RESEARCH CENTRE



SZÉCHENYI 2020

HUNGARIAN GOVERNMENT

European Union
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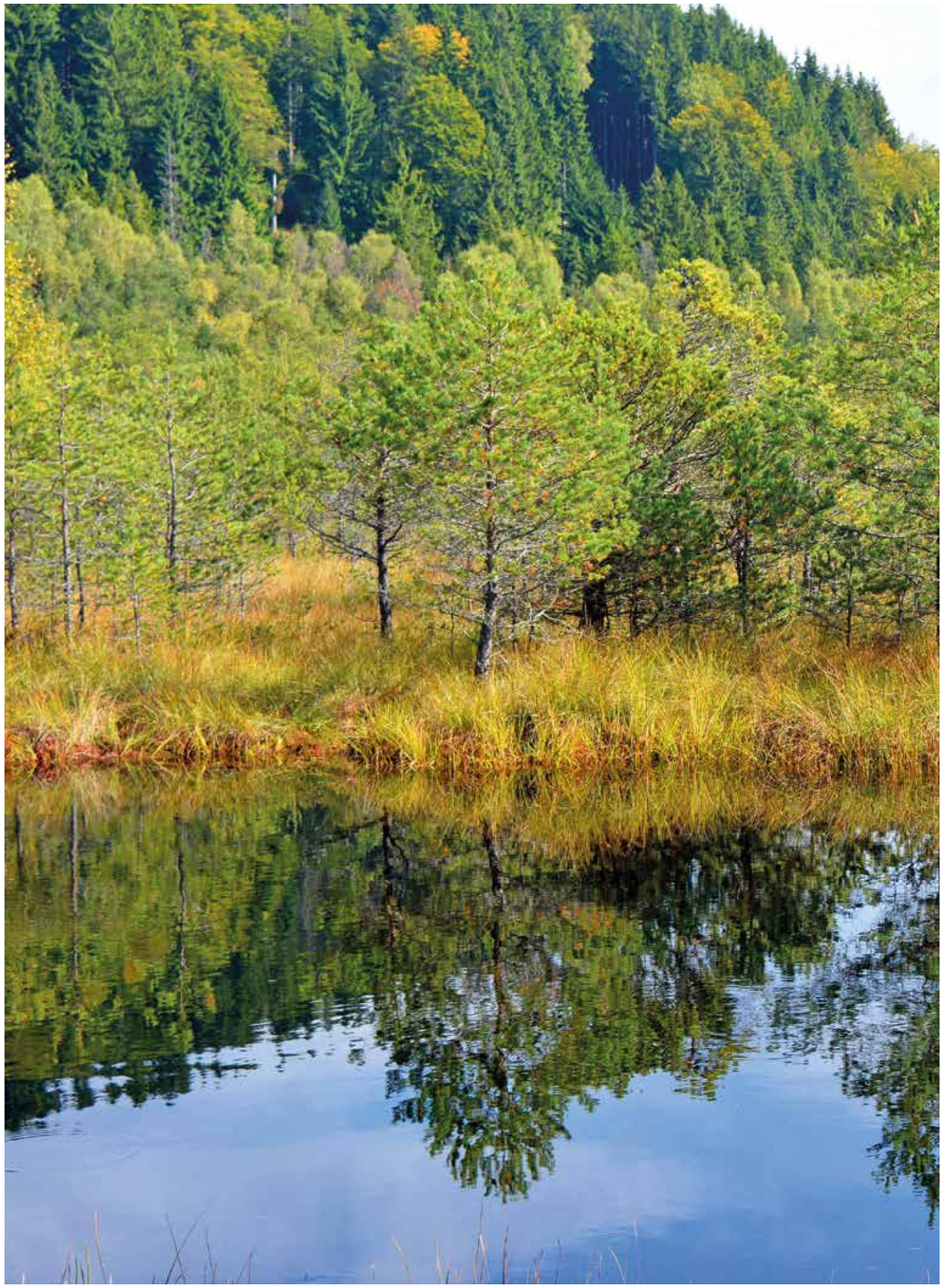
INVESTING IN YOUR FUTURE

GINOP-2.3.2-15-2016-00009



GOALS

Strengthening the abilities for research and development in recent and palaeo-environmental geochemistry

The present project covers a wide dynamic research field from past climate to recent environmental chemistry. Development of the research infrastructure plays a significant role, being an independent research topics. These activities will be utilized in applied research.

11
new research employees

73
scientific publications

20
research topics

14
PhD degrees

7
new research infrastructure

ATOMKI

Founded in 1954

The Institute for Nuclear Research, in short Atomki, situated in Debrecen, is one of the member institutes of the Eötvös Loránd Research Network. The primary activity of the Atomki is devoted to microphysical research for the understanding of the laws of nature, which contributes to the results of scientific research in the world, and to the sustainability of the scientific and technological culture in Hungary.

INTRODUCTION

CONTENT

RESEARCH

CLIMATOLOGY-PALEOCLIMATOLOGY

HYDROLOGY-PALEOHYDROLOGY

GEOCHEMISTRY-ENVIRONMENTAL GEOCHEMISTRY-GEOLOGY

INFRASTRUCTURE

INFRASTRUCTURE

EVENTS

TIMELINE

TIMELINE

Start of GINOP project
1 September 2016

Opening conference
3 March 2017

Visiting the Isotope Laboratory of Xi'An Jiaotong University, China
20 December 2017

Fermi Award of the Hungarian Nuclear Society
3 December 2018

Closing conference

End of GINOP project
20 August 2020

2016

2020

Installation of a precipitation collector at the Mohos peat bog
12 September 2016

Groundwater sampling in Bulgaria
1 October 2016

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Groundwater sampling in Morocco
16 May 2017

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Sediment sampling of „Tăul fără fund" peat bog (Băgău village, Romania)
15 October 2017

Water sampling as a part of paleoecological study of high mountain lakes in the Retezat Mountains
10 December 2017

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Sampling of Quaternary river sediments in the Pannonian Basin
16 January 2018

Sediment and plant sampling from high mountain lakes in Macedonia
20 February 2018

Speleothem-based paleoclimate study and installation of precipitation collectors in karst areas in Macedonia
23 April 2018

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Paleoclimate reconstruction of the Amazon rainforest in Ecuador based on speleothems and tree rings
5 May 2019

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^{39}Ar age dating of drinking waters in South Africa
11 October 2019

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Date of this issue
1 December 2019

TIMELINE

Further information: **https://iker.atomki.hu/en/events**

ISOTOPE CLIMATOLOGY AND ENVIRONMENTAL RESEARCH CENTRE

The main focus of the Institute for Nuclear Research in Debrecen is basic research in the field of atomic, nuclear and particle physics and the application of the results.

The research direction of the newly-established Isotope Climatology and Environmental Research Centre (ICER) involves those interdisciplinary topics in which physical methods can be applied in other fields (geology, hydrology, meteorology, biology, history and environmental protection) to fulfil the aim of the project.

Related topics are organized necessarily around a major group of instruments or a certain method. The functioning of the studied substances coming from a geological and anthropogenic sources can be understood sufficiently only by taking into account their effects on each other. Thus, the concentrated presence of methods and topics in the Institute for Nuclear Research obviously contributes to their individual success.

The significance of the environmental physical research at the institute and the HEKAL group (part of the institute) is shown by the SKI qualification/grade (research infrastructure with strategic importance) received in 2010. This grade was given by the National Research Infrastructure Survey and Itinerary Project (NEKIFUT). The HEKAL group consists of eight different environmental physical research entities within the institute.

Multicollector inductively coupled plasma ion source mass spectrometer (MC-ICPMS)

RESEARCH

RESEARCH

RESEARCH

CLIMATOLOGY-
PALEOCLIMATOLOGY

During Earth's history, the climate has also changed constantly, while most antropogenic activities also left their mark directly or indirectly on weather phenomena and climate change.

Therefore, climate and paleoclimate research has become increasingly important today to get to know and understand the cause-effect relationship of climate changes in the past. Their accurate documentation greatly contributes to the reconstruction of the past environment.

A better understanding of various open and closed systems provides the necessary knowledge of global climate change that causes increasingly extreme weather conditions. In some materials of the biosphere (eg. tree rings, lake sediments, cave-carbonate formations, paleosols, bones), certain features of prehistory have been preserved excellently.

For example, they provide us with information about changes in the Earth's carbon cycle, extreme cosmic radiation, the past 15,000 years of climate and rain intensity, as well as about glacial periods. All this research opens up new perspectives for collaboration between science and society.

Radiocarbon dating
of bones

1.1 CARBON IN THE ATMOSPHERE GREENHOUSE GASES AND AEROSOL

Besides CO_2, other components like carbon monoxide, methane and aerosol will be investigated focusing on the ^{13}C and ^{14}C isotope composition. High temporal resolution and long-term observation will be combined in urban areas as well as in a background rural site. The source distribution of these greenhouse gases can be revealed in a state-of-the-art manner.

Picture 1.1:
Monitoring station for greenhouse gases at ICER, Debrecen.

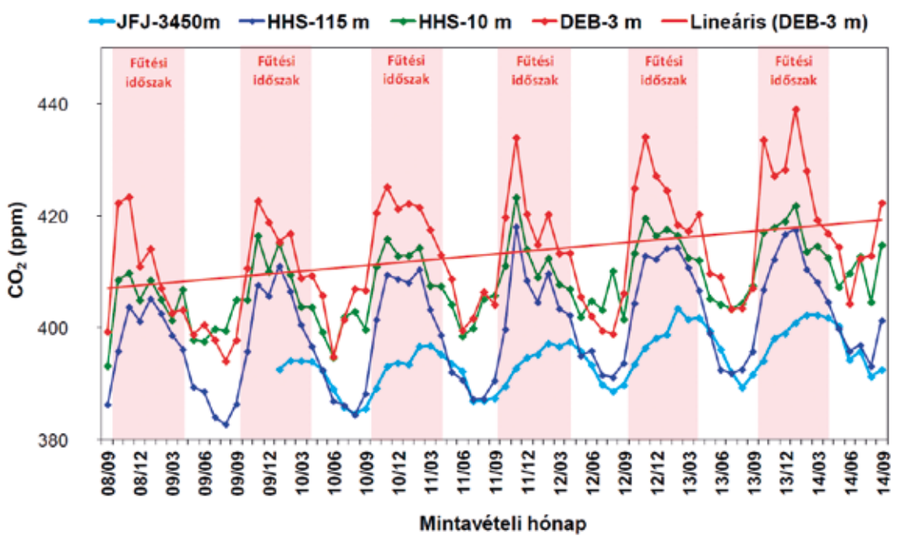
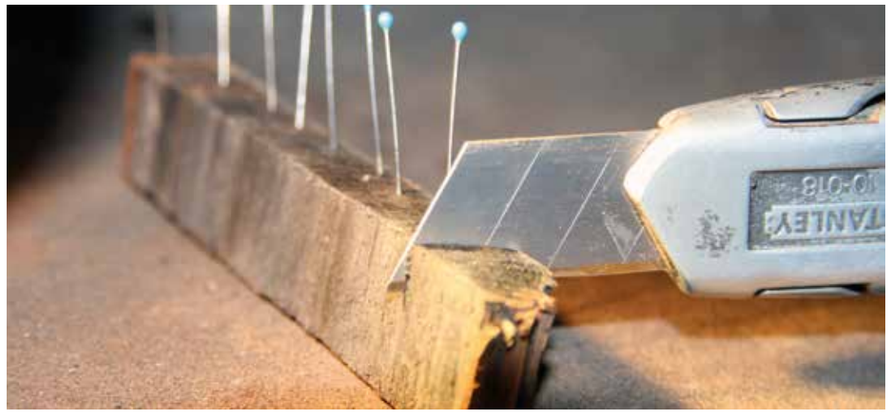


Figure 1.1:
Rising of the atmospheric CO_2 of a 6-year time series in an urban (Debrecen, Deb) and a rural environment (Hegyhátsál, HHS), and in the Swiss Alps (Jungfraujoch, JFJ).

1.2 TREERINGS AS ARCHIVES

High-precision carbon isotope analyses of tree rings sequences of thousands of years are used to understand long- and short-term changes in the global carbon cycle, biosphere and vegetation. As a partner group, we join an international research targeting to reveal the extreme galactic cosmic ray (GCR) events that occurred in the past 2500 years. The research focuses on the polar region when searching for tree rings as archives of sudden changes of GCR. Trees from the southern hemisphere will be used to study the spatial distribution of the effect of GCR events.



Picture 1.2:
Separation of tree rings for isotope analysis.

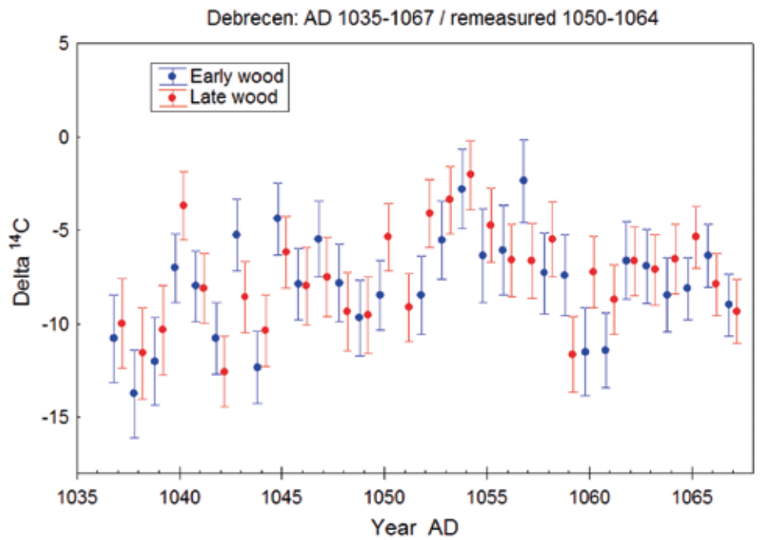


Figure 1.2:
Variation of cosmogenic ^{14}C of tree rings grown between 1035 and 1067 AD.

1.3 RECONSTRUCTION OF PALAEOENVIRNOMENTAL PROCESSES BY ANALYSIS OF LACUSTRINE SEDIMENT AND PEAT SEQUENCES

The aim of this projec is the reconstruction of climatic events and human impact in the past 15 kyr preserved by the sediments, accumulated in high mountain lakes. These lakes are sensitive to the environmental changes.

Picture 1.3:
A peat core drilled in the Mohos peat bog, Ciomadul Mts. Eastern Carpathians.

Environmental events occurred on the catchment area may result signals in the elemental and isotopic composition of sediments. High mountain lakes were selected for the study from the Carpathians. Peat bogs will be also investigated within the framework of this study. One important site will be the Mohos (East-Carpathians, Romania), where the large peat deposit preserved the environmental history of the past 10 thousand years.

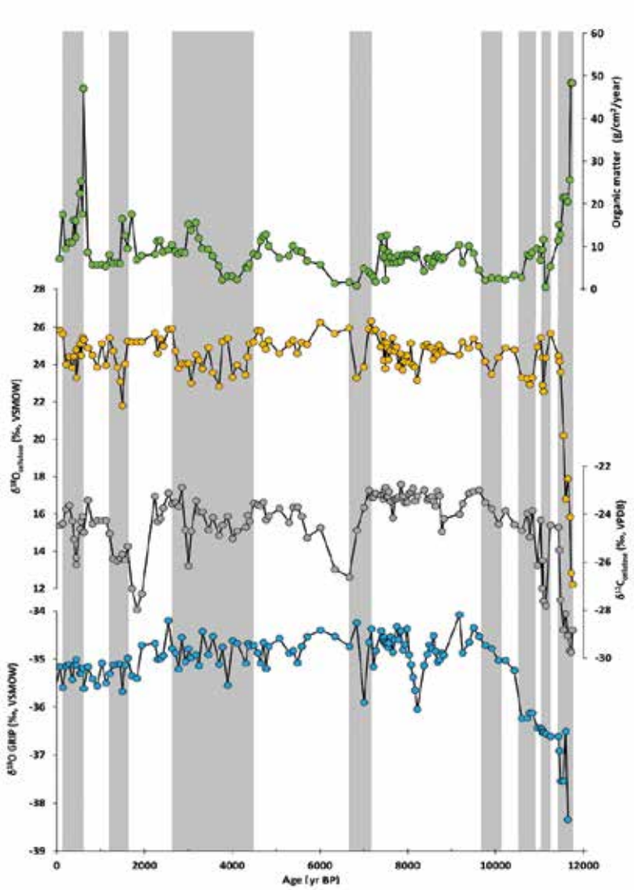


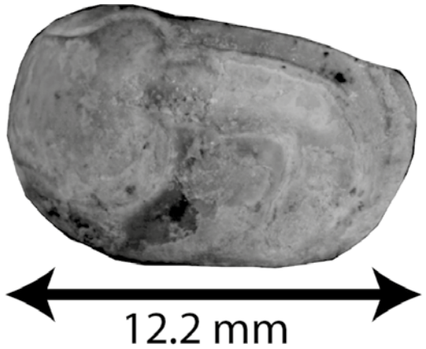
Figure 1.3:
Analytical results of the peat core: accumulation of organic matter (green circles), oxygen (yellow circles) and carbon (grey circles) isotope composition of the cellulose component of the Sphagnum. Isotope composition of Greenland ice core helps comparing (blue circles).

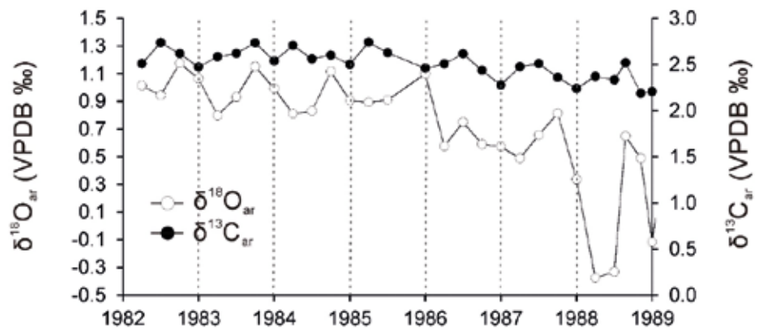
1.4 ISOTOPE GEOCHEMISTRY AND THERMOMETRY FROM CARBONATE DEPOSITS

One of the research directions in this topic will be clumped isotope thermometry on freshwater carbonate deposits. In addition, biogenic carbonates will be a novel field of application.

For instance, clumped isotope analysis of fossil otoliths will help to achieve the first quantitative water temperature reconstruction for the late Miocene Pannonian Lake.

Further investigations include the examination of shells of marine and freshwater bivalves, which can be used to examine seasonal events over a period of 100 years.





1.5 PALEOCLIMATE ANALYSIS OF CARBONATE FORMATIONS FROM CAVES

The investigation primarily intends to reveal past climate conditions. The laser ablation MC-ICP-MS technique will provide possibility to obtain a higher spatial resolution for the age-definition of the studied samples.

This technique along with clumped isotope measurements and with fluid-inclusions analysis provides unexplored possibilities in the reconstruction of paleoclimate parameters.

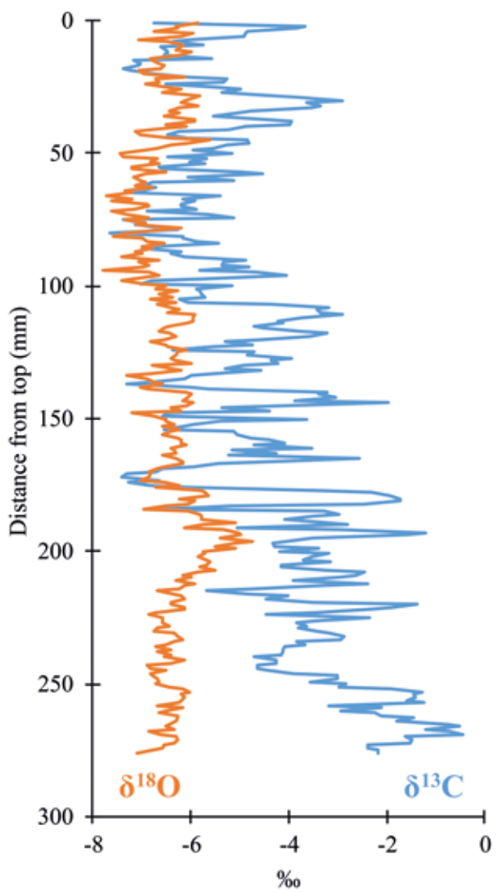
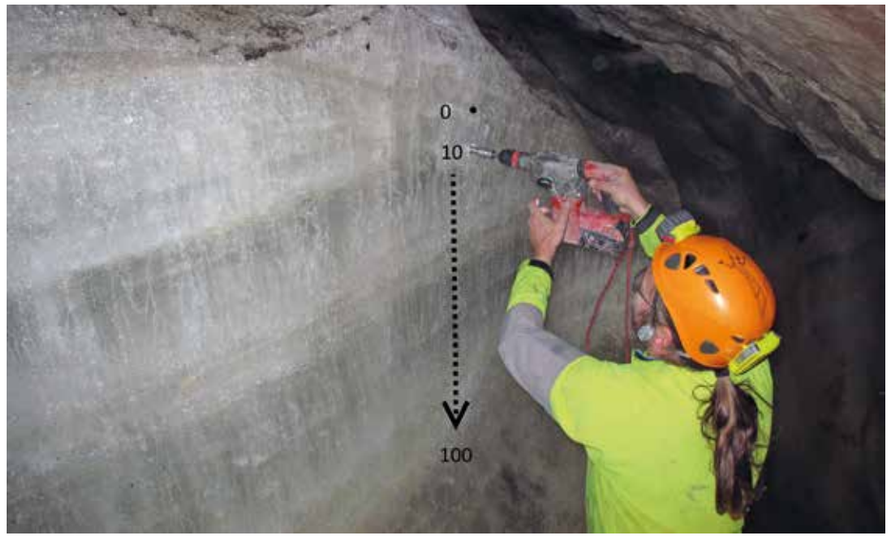


Figure 1.5:
Variation of oxygen and carbon isotope composition of SD1 along the growth axis.

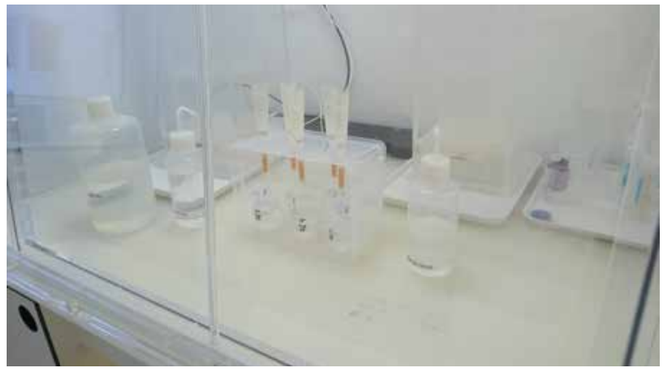
Picture 1.5:
SD1 stalagmite from Samoska Dupka Cave, North Macedonia.

1.6 ANALYSIS OF DETRITAL MATERIALS FROM CAVE ICE DEPOSITS AND POLAR ICE CORES



Picture 1.6.1:
Ice coring in the Dobsina Ice Cave.

Elemental concentration (Sr, Cr, Cu, Pb, Zn) measurements and isotopic analyses (e.g. Sr, Pb) will be performed for the first time on cave ice sections located close to historically important industrial centers, which may help in identifying source regions or changes in processing technologies. Besides trace-element analyses, the study of stable-isotope data of water will allow the tracking of past climate changes, and more importantly, that of the regional-scale variations of atmospheric circulation. The primary aim of the analysis of ice core samples is constraining source regions of dust accumulated on Greenland during the Last Glacial Maximum.



Picture 1.6.2:
Separation of hafnium, strontium and neodymium using ion exchange chromatography.

1.7 EXPOSURE AGE DATING OF ROCK SURFACES USING IN-SITU PRODUCED COSMOGENIC ^{14}C FOR A BETTER UNDERSTANDING OF PAST LANDSCAPE EVOLUTION

The research will focus on the paleoclimate reconstruction using in-situ produced cosmogenic ^{14}C for the exposure age determination of glacial landforms and methodological development for the extraction and measurement of in-situ produced cosmogenic ^{14}C from quartz.

Main objectives of the research:

1. Launching an in-situ produced cosmogenic ^{14}C laboratory in Hungary.
2. A better understanding of the Late Quaternary glaciations in the Southern Carpathians, with major emphasis on the deglaciation process and climate change following the last glacial maximum.

Bucura glacial valley in the Retezat Mts., Southern Carpathians

Figure 1.7.1:
Bucura glacial valley in the Retezat Mts., Southern Carpathians. Photo: Zsófia-Ruszkiczay-Rüdiger.

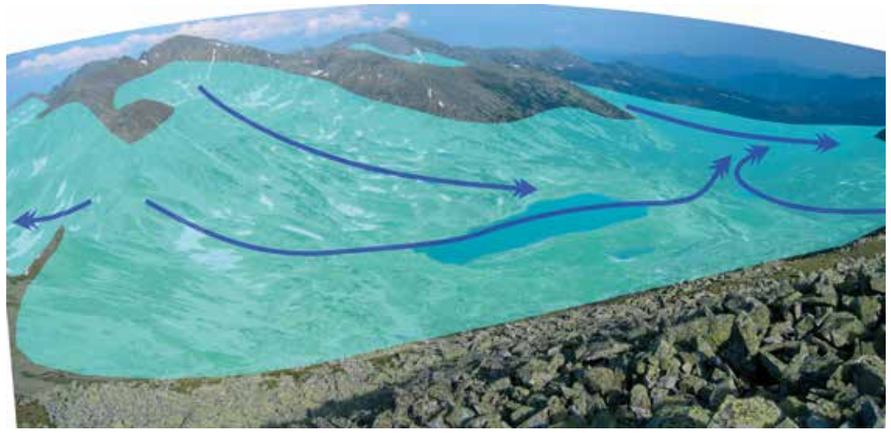


Figure 1.7.2:
The maximum extent of the glacier in the Bucura valley.

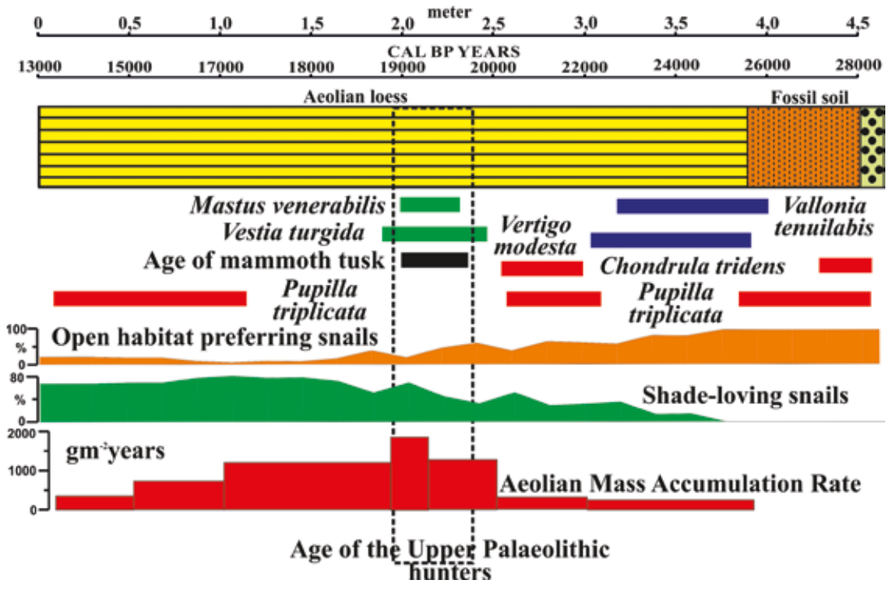
1.8 RESEARCH ON BURIED PALEOSOILS

The major goal of this research is the reconstruction of climatic and environmental changes occurred during/around the termination of the last glacial period and early Holocene.

Resolution of soil profiles to be investigated is on the order of 10 years, which allows for their comparison with global records. The clumped isotope method will be used on selected secondary carbonates. One of the key questions to be addressed is whether the Dansgaard-Oeschger (D-O) cycles and Heinrich events were recorded in the upper, youngest part of the loess sequences.

Picture 1.8:
Vertigo modesta (cross whorl snail), a psychrophilic snail, found in the Szeged-Öthalom loess layers (Pál Sümegi, 2018).

Figure 1.8:
Geochronological, sedimentary, anthracological and malacological results of the Szeged-Öthalom cross section (Pál Sümegi, 2018).



1.9 INVESTIGATING LATE QUATERNARY MEGAFAUNA EXTINCTION IN THE CARPATHIAN BASIN

Megafauna elements gradually disappeared from the Carpathian Basin during the last glacial maximum and in the subsequent Late Glacial period. The aim of this project is to apply AMS ^{14}C dating on Late Weichselian bone collections of major Hungarian museums and to clarify this way the possible extinction time of the megafauna members. The second aim is to compare extinction times with coincident paleoenvironmental and paleoclimate changes in the Carpathian Basin inferred from the paleoecological study of lake sediments. In addition to radiometric dating, animal bones will be subjected to stable isotope measurements ($d^{18}O$, $d^{13}C$, $d^{15}N$) that will be used to reconstruct temperature changes between 12 to 30 thousand years ago, and to draw inference for the diet requirements of the megafauna elements and their yearly migration between regions.

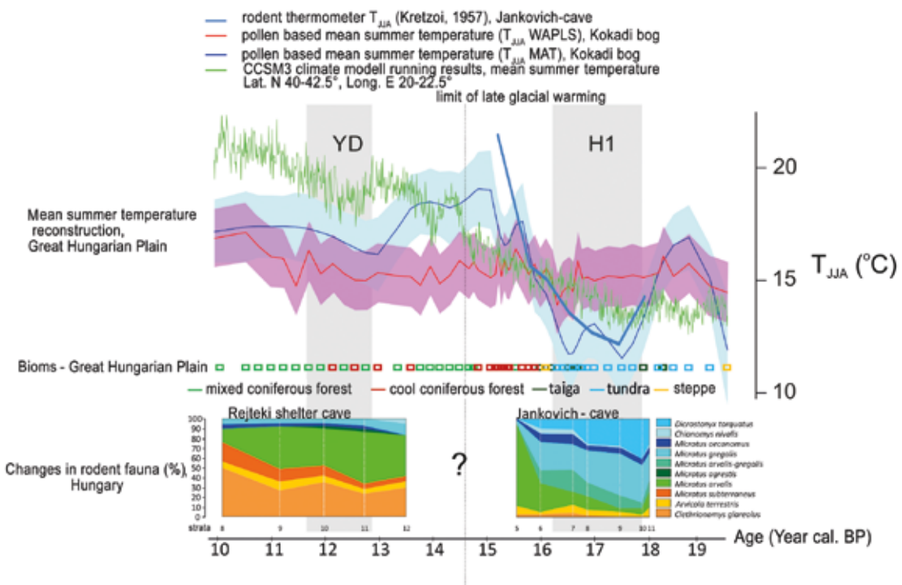


Figure 1.9:
Variation of mean summer temperatures, continental vegetation, distribution of the rodent species at the end of the last glacial period (between 19 and 10 kyrs).

Picture 1.9:
18,000-year-old mammoth teeth found in Pilismarót, planned for temperature reconstruction based on the isotope compostion.

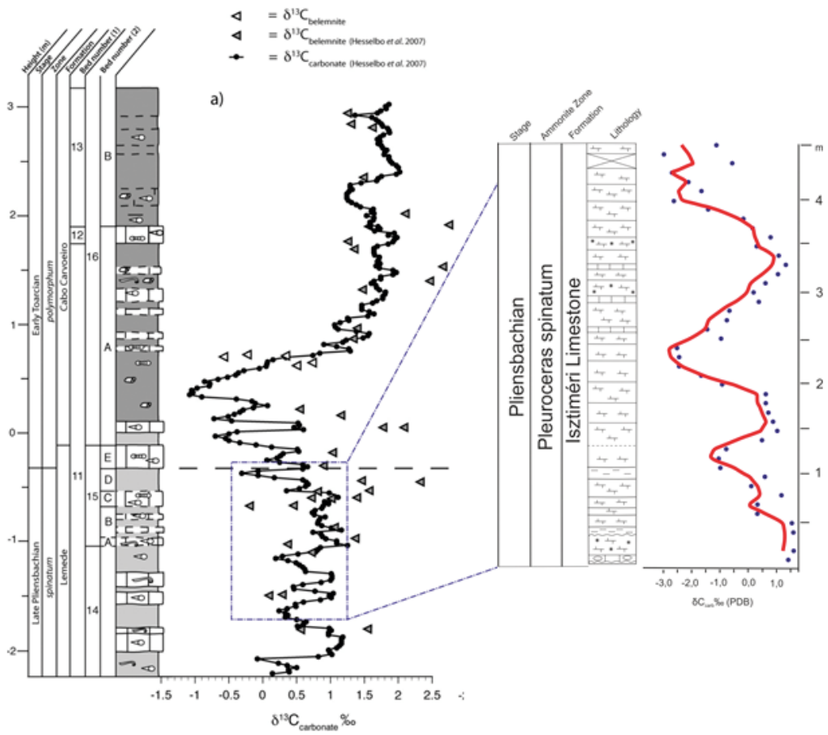
1.10 CLIMATE CHANGE IN THE MESOZOIC

During the Mesozoic the mainly greenhouse climate was divided by a number of short and rapid climatic changes, mainly warming events. The changes taking place in the Tethys Ocean can be reconstructed using geochemical proxies from the high-resolution samples of Triassic, Jurassic and Cretaceous marine sediment successions taken from six outcrops in Hungary.

Our aim is to understand the processes of the geological system from the Late Triassic to the Early Cretaceous, over an interval of about 80 million years during which six main events took place.

Picture 1.10:
The Triassic-Jurassic boundary in the Kálvária Hill of Tata, Hungary.

Figure 1.10:
Carbon isotope composition of a lower Jurassic sediment (Pliensbachian-Toarcian boundary) in Bakonykút, Hungary, compared to a Portuguese reference time series.



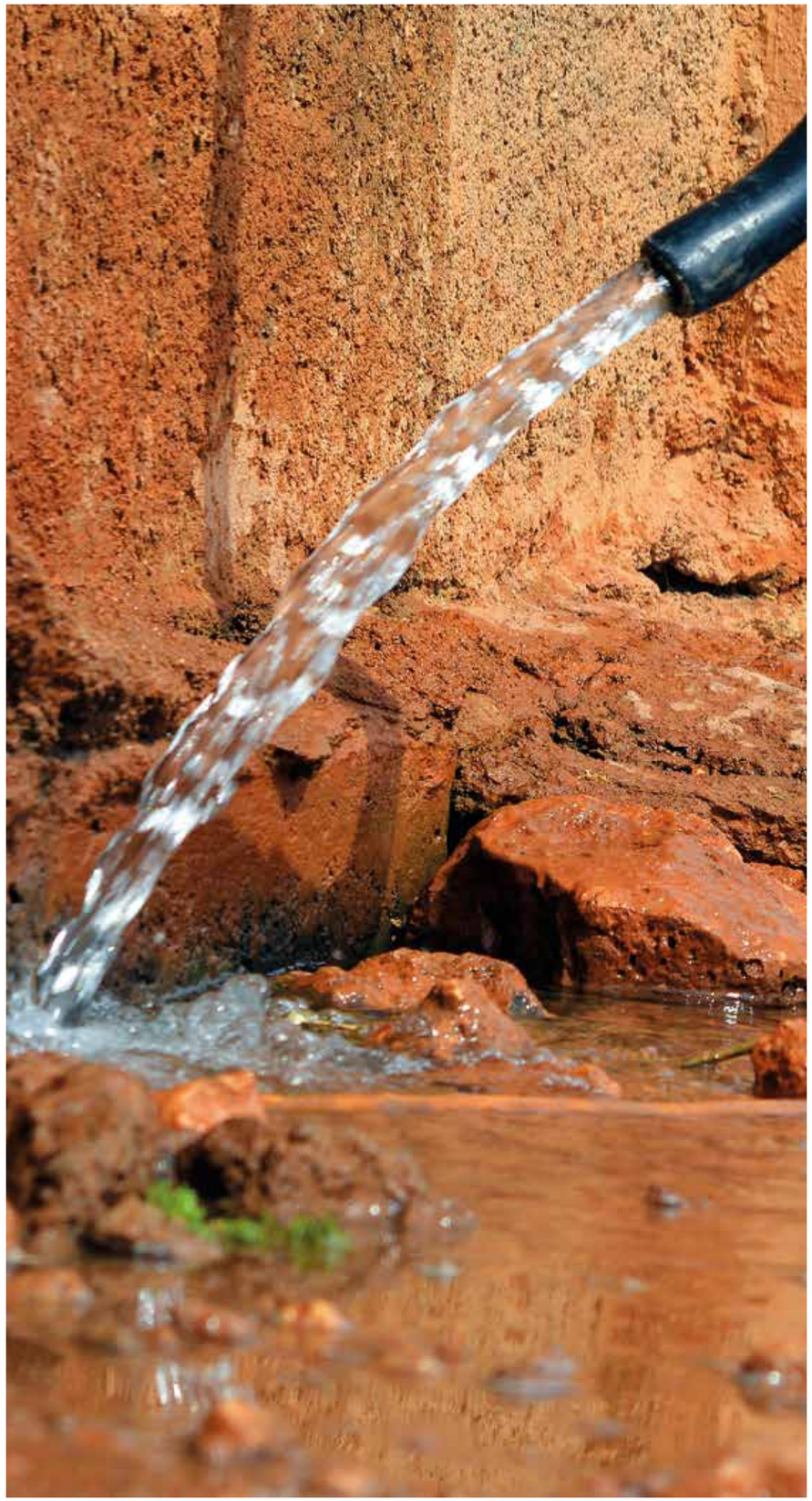
HYDROLOGY-
PALEOHYDROLOGY

The increasingly intense development of society and technology plays an important role in the exploration of groundwater drinking water sources.

The investigation of the occurrence and distribution of terrestrial waters, their physical and chemical properties and their interaction with the environment has become essential. There are a number of research areas to explore paleohydrological events. A specific example concerns the age determination of the plain waters of the Great Hungarian Plain, the temporal changes of anthropogenic effects, and research of the current and past dynamics of our rivers.

There have been a number of procedures for determining water age, but these have proved methodologically too complicated or too expensive. A new, perspective dating alternative is the introduction of ^{39}Ar and ^{85}Kr isotopic methods. One of the great treasures of Hungary is the thermal springs, whose sustainable use and preservation requires more knowledge of the natural processes that created them.

Water protection and research are among the top priorities in recent decades and today



2.1 PALAEOCLIMATE RECONSTRUCTION USING GROUNDWATER AS AN ARCHIVE

The only direct way to reveal palaeotemperatures is the calculation of solubility temperatures from noble gas concentrations dissolved in groundwater.

To better understand how temperature has changed during the transition of Pleistocene/Holocene, we intend to broaden our view outside the Carpathian Basin. The following aquifers will be studied in the upcoming research period: Fratesti Aquifer, Romania; Pontian Aquifer, Bulgaria; and Turonian Aquifer, Morocco.

Picture 2.1:
Groundwater sampling in Bulgaria

2.2 RADIOCARBON DATING OF AQUIFERIC WATERS ON THE HUNGARIAN GREAT PLAIN

Numerous radiocarbon dating studies were carried out on drinking water aquifers of Great Plain in the past 20-30 years. Millions of cubic meter water were pumped out from these aquifer layers since then. The goal of this study to find out how the age distribution of the investigated water bodies has changed as a result of production and how it influences the maintainable utilization of the most significant water resources.

Picture 2.2:
Sampling of thermal water in the Great Hungarian Plain.

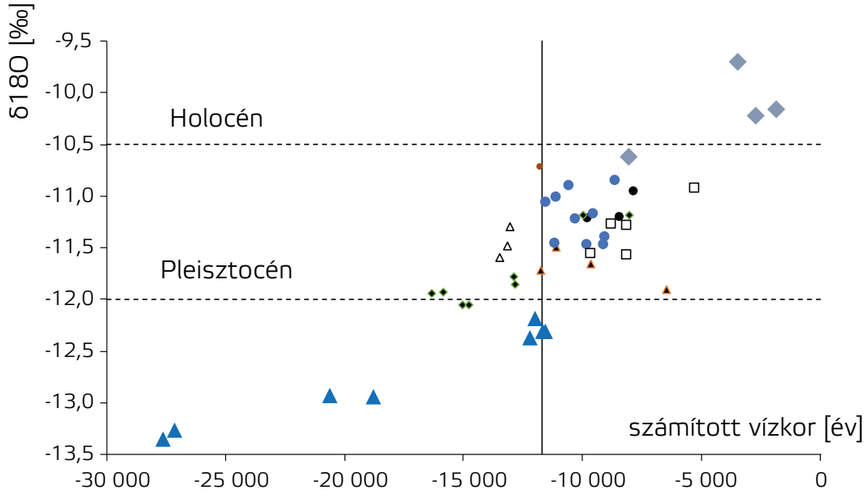


Figure 2.2:
Oxygen ($\delta^{18}O$) and carbon (^{14}C) isotope signatures of the pore water in the Mórágy granite, Hungary.

2.3 NOVEL AND ALTERNATIVE AGE DATING METHODS OF SUBSURFACE WATER (^{39}AR, ^{85}KR)

The half-life of ^{39}Ar 269 years, which makes it possible to fill the gap between the application range of the tritium and radiocarbon water age dating methods. In spite of complicated measurement technology, there is a huge demand for it not only in the scientific community, but also in the field of sustainable use of water resources.

Only few laboratories are able to carry out such measurement method routinely in the World (Bern, Chicago, Heidelberg). The purpose of this development is to construct gas proportional counter tubes, which are capable of precise and accurate measurement of ^{39}Ar. The system will be installed in the underground National Laboratory of Gran Sasso (www.lngs.infn.it).

Beside of ^{39}Ar measurement the device is also capable of determining the ^{85}Kr content of the investigated samples, which allow of the age dating for young waters (<60 years).

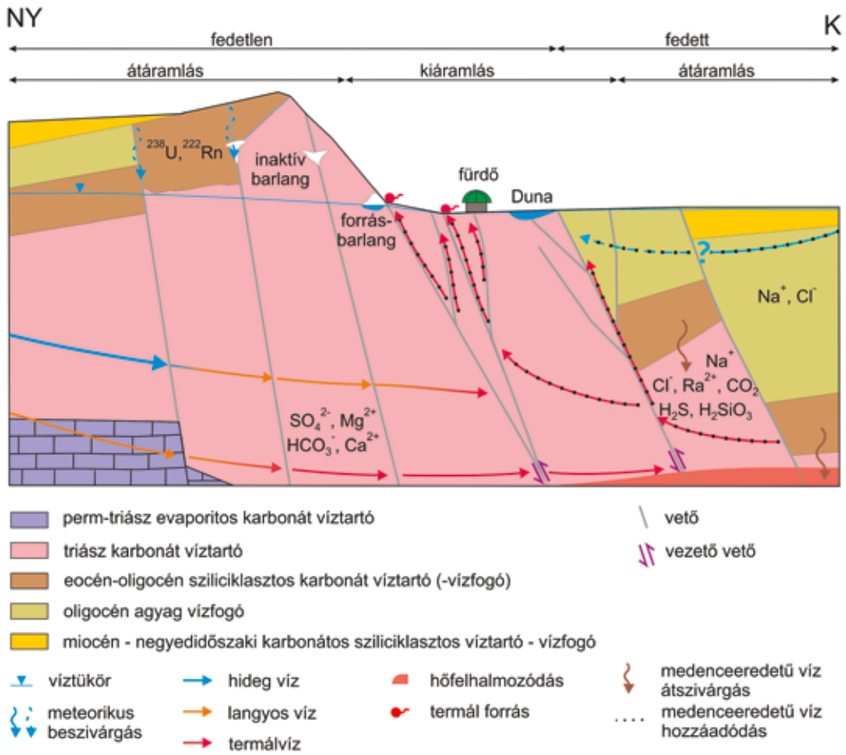
Picture 2.1:
Field sampling of groundwater for ^{39}Ar and ^{85}Kr in the Buffels River Valley, South Africa.

2.4 EXAMINATION OF THERMAL WATER AND THERMAL SPRINGS FOR THEIR SUSTAINABLE UTILIZATION

The understanding of natural processes giving rise to thermal waters are essential for the sustainable utilization of the latter. The research work aims at the parallel interpretation of recent processes, as well as those manifested in analogous past geological phenomena. The evaluation of recent processes and sampling are carried out in spring caves, wells and in-situ experiments.

Picture 2.4:
Biogeochemical precipitation on the natural fractions of the primary spring in Gellért Mt., Budapest, Hungary.

Figure 2.4:
Groundwater flow model of the Gellért Mt.



2.5 PALAEOMORPHOLOGY OF ANCIENT RIVERBANKS

The planned research aims at a wide range of investigations in the topics of geomorphology and the water supply of oxbows along River Tisza and its tributaries. The primary aim is to determine the age of the river beds and the deposited sediments based on the pace and characteristics of lateral erosion of rivers. Besides, we also focus on the spatial distribution and temporal intensity of floodplain accumulation using isotope geochemical techniques.

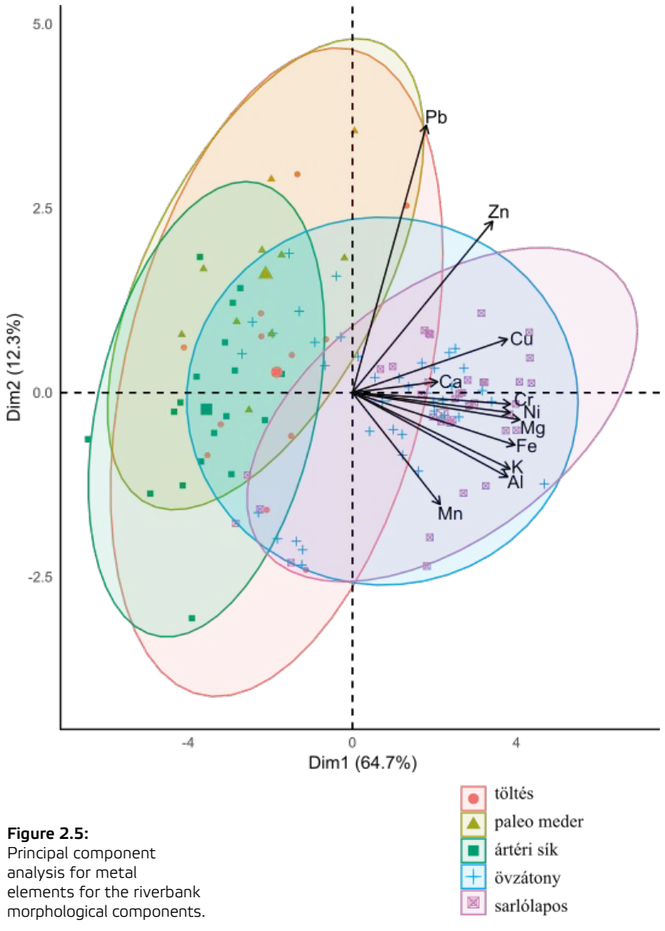


Figure 2.5:
Principal component analysis for metal elements for the riverbank morphological components.

Picture 2.5:
Soil cross section in the riverbank of Tisza.

Sampling recent fluvial sediment at Sajó River

HYDROLOGY-PALEOHYDROLOGY

GEOCHEMISTRY-ENVIRONMENTAL GEOCHEMISTRY-GEOLOGY

Successful research can only be done on the basis of detailed analytical work.

The combined use of these three heterogeneous disciplines: geochemistry, environmental chemistry and geology provides an opportunity to interpret complex systems around us. It is necessary to develop modern, precision sets of instruments, to develop and implement new methods, to evaluate the results in multiple aspects and to correlate them. Overall, the combined application of these applied sciences is realized in the Isotope Climatology and Environmental Research Centre.

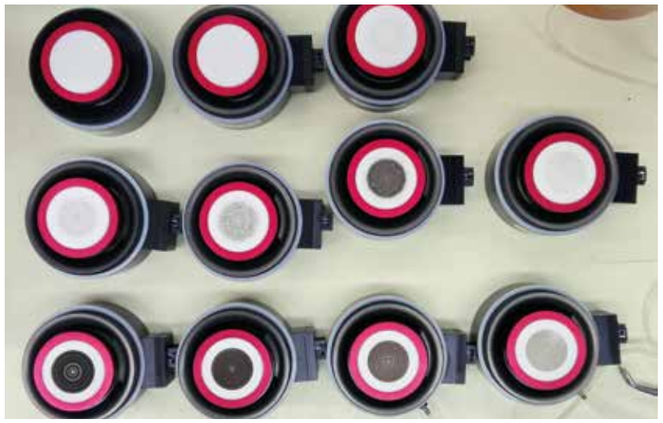
This interdisciplinarity extends from the examination of the Great Hungarian Plain to the processes in the Earth's mantle and through the atmospheric aerosols to specific examples in the isotopic examination of the dacite mineral components of the Csomád-mountains of Transylvania.

RESEARCH

3.1 ATMOSPHERIC AEROSOLS

The main objectives of the project are to determine the sources and source contributions of particulate matter pollution in urban, rural and remote sites, to characterize the short- and long-term tendencies, to establish the dependence of source contributions on local meteorological parameters, natural processes and human activities, and to develop adequate analytical techniques for these purposes.

Further objectives are to identify and characterize the local, regional and transboundary aerosol sources, to determine the potential source areas of particulate matter pollution.



Picture 3.1:
Aerosol samples of different fractions collected in an urban area during a smoke warning (Photo: Zoltán Szoboszlai).

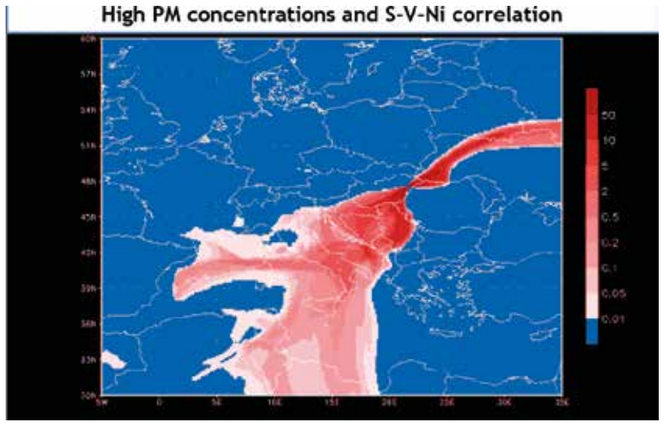


Figure 3.1:
Distribution of sulphate from oil burning modelled by SILAM (http://silam.fmi.fi). Trace elements for oil burning were V and Ni.

3.2 STUDYING THE CRYSTALLINE BASEMENT OF THE GREAT HUNGARIAN PLAIN

The purpose of this project aims at studying the subsidence and exhumation history of the crystalline basement of the Great Hungarian Plain, which is essential in the research for unconventional hydrocarbon reservoirs. Within the frame of the project, the $^{40}Ar/^{39}Ar$ radiometric age dating method, determination of the Cl/I/Br ratios in fluid inclusions, as well as the fission track methods will be established in our institute. Introduction of the new methods will facilitate conducting volcanological, sedimentological and economic geology related research projects as well.

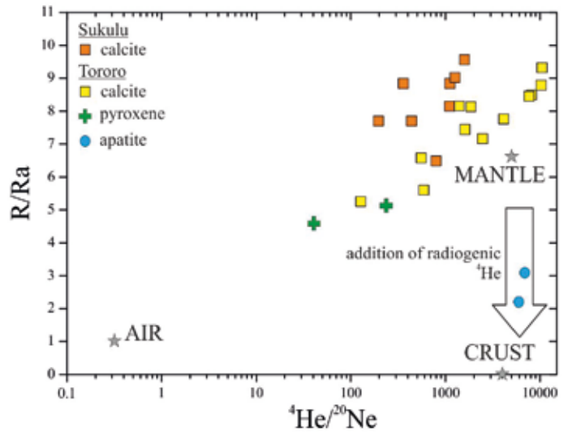
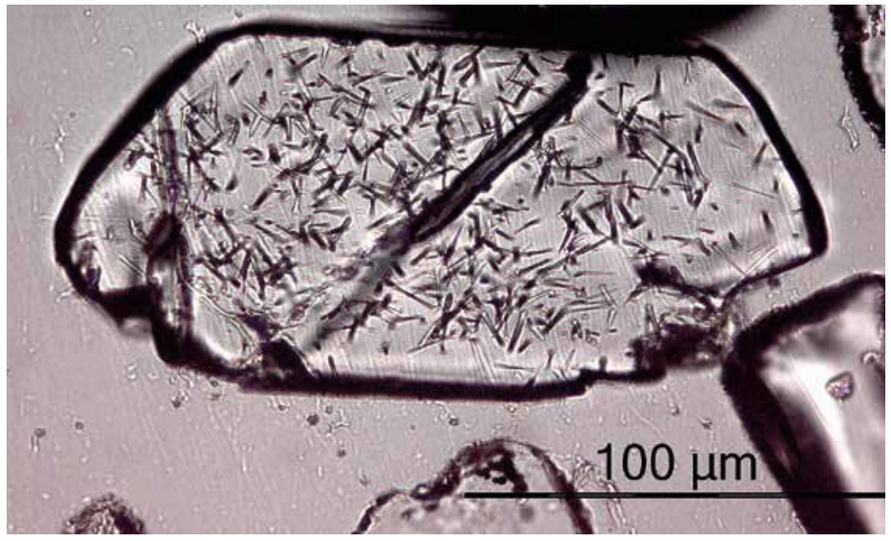


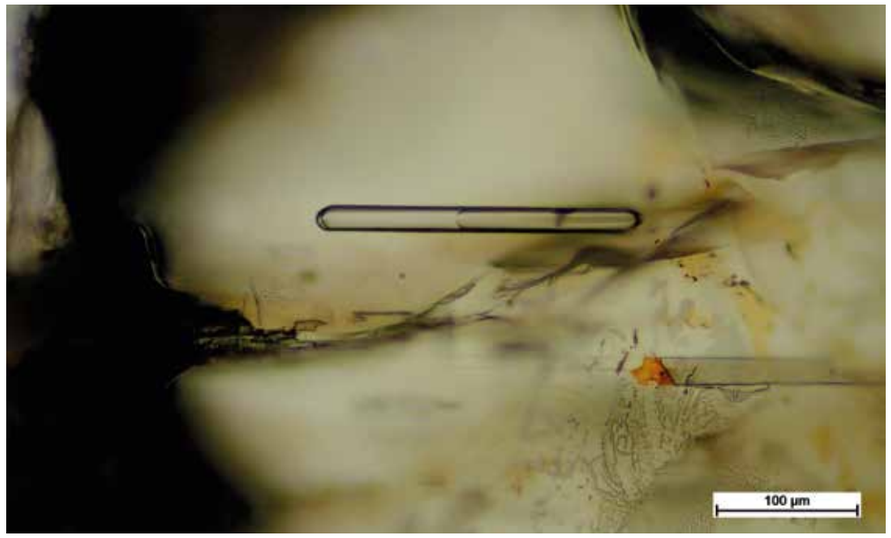
Figure 3.2:
Helium and neon isotope ratios from fluid inclusion of two carbonatite samples from Uganda.



Picture 3.2:
Apatite mineral after acidic digestion with tracks of spontaneous fission of uranium.

3.3 STUDYING UPPER MANTLE ROCKS

The major goal of this project is to unravel the small- and large-scale heterogeneity and temporal change of Earth's mantle by use of fluid inclusions. Determination of the volatile content (C, O, H, N, He) and isotopic composition of mantle fluids, relying on fluid inclusion petrography, will provide better understanding of the origin and evolution of volatiles in the upper mantle.



Picture 3.3:
Fluid inclusion of 130 µm of mantle origin. Two phases appear: a gas phase and two liquids (CO_2 and H_2O) .

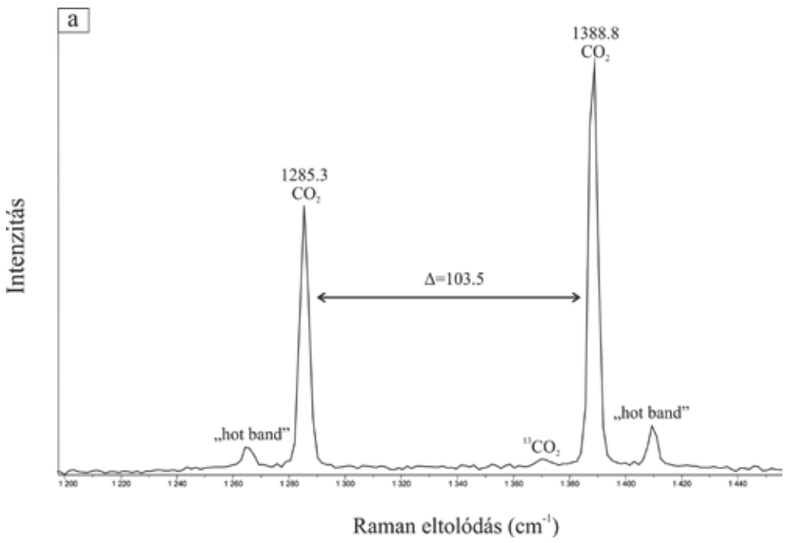


Figure 3.3:
Raman spectrum of liquid CO_2 in the fluid inclusion. The distance of the two intense peaks help revealing the density of the CO_2.

3.4 VOLCANOLOGICAL STUDIES IN THE CIOMADUL, EAST CARPATHIANS

Isotope ratios of mineral phases (e.g., $^{87}Sr/^{86}Sr$ in plagioclase and Hf isotope ration in zircons) in the dacitic volcanic product of Ciomadul are used to constrain the origin (mantle and/or curstal sources) of the magmas and reconstruct the magma mixing processes in the crustal magma reservoir.

The inner compositional variation of the crystals provides information about the timescale of the reactivation of the crystal mush. Regular analysis of the isotope composition and the flux of the emitted CO_2-rich gases are used to infer about the origin of the gases.

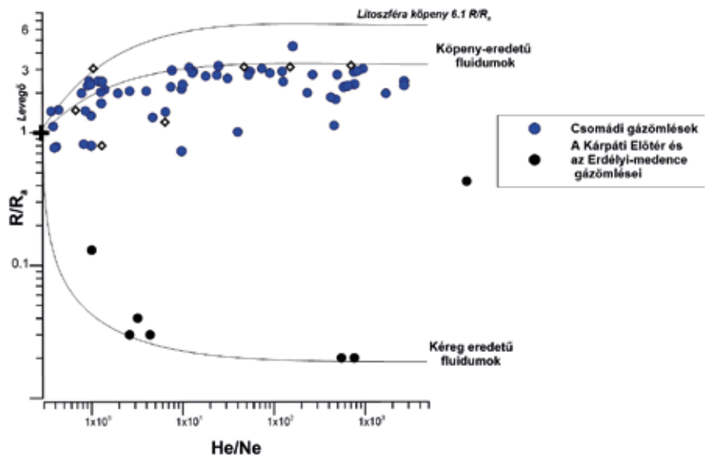


Figure 3.4:
Helium and neon isotope ratios from volcanic gases in Ciomadul Mts. Eastern Carpathians.

Picture 3.4:
Bubbling pond at Apor lányok feredője (Bálványos, Eastern Carpathians).

3.5 APPLIED RESEARCH IN GEOCHEMISTRY

> **Determination of the age of melting events in meteorites.**
During the research, the enclosure age will be determined which, provides an absolute date either for the time of birth of the meteorite or the event of the re-melting. About 1 g of rock will be heated in order that the isotope ratios of the extracted gases are analysed. Additionally, $^{204}Pb/^{206}Pb$ and $^{207}Pb/^{206}Pb$ ratios will be determined by a MC-ICPMS. The method will be verified with existing meteorite samples of known age. Hence, comparing the results of new samples help us study the origin and the parent planet of the meteorites. The research strongly contributes to reveal ancient processes of the solar system, the number and variation of the planet embryos, and the early evolution of terrestrial planets.

> **Characterisation of iron ferrules in soil.**
The aim of this work is to study the pH-dependency of iron ferrule formation in a wide range in wet soil (from stagnic luvisol to solonetz) layers in Hungary, namely the parameters influencing the crystal type and the crystallisation, as well as the vegetation show a wide variability. After the petrographic, geochemical and soil characterisation of the collected samples, iron ferrules are separated from the root level and the matrix. After the mineralogical characterisation (XRD, TEM), micro-texture (BSE images), chemical (EPMA) and petrographic (microXRD) analyses will be performed. The main groups of iron ferrules will be identified, and then the MC-ICPMS measurement will be executed for iron isotope ratios.

> **Archaeometrical applications: determinantion of origin of raw materials by radiogenic isotope geochemical methods.**
Metals (Pb, Cu, Sn, Fe. Sb, Mn, Co) were widely used throughout the history of glass-making for modifying the properties of glass, as well as decolourizing agents. In case of favourable conditions, metals from different mining areas have characteristic isotope ratio, so that metals from different origins can be identified. The isotopic measurement of Pb has been extensively studied worldwide and is considered the most promising method, however, we are making experiments to develop novel methods, such as Cu, Fe and Sn isotope measurements. The impurities of metals (e.g. Fe, Sb, Zn, Co, Bi, Ni, Sr) may reflect the composition and provenance of ores, and can be measured by trace element analytical methods. The results of these measurements can be used to determine the difference/identity of raw materials used by historical glass manufacturers, and the distinguishing of their products.

Field sampling at the Lake St. Ana, Eastern Carpathians, Romania.

> **Environmental geochemical analysis of carbon nanotubes.**
The aim of the research is to apply isotope analytical methods to analyse physical/chemical properties of nanomaterials/nanocomposite materials. Radiocarbon (^{14}C) content, carbon/nitrogen ratio (C/N) and $\delta^{13}C$, $\delta^{15}N$ of peroxidase enzyme was investigated to monitor the changes of different parameters during sample preparation, storage and usage of composites. Protein content of peroxidase/carbon nanotube composites (single wall and multi wall) was determined as well. We used our earlier experience in combustion and measurement protocols with carbon nanotubes and peroxidase enzyme during data analysis. Specific enzyme activity of peroxidase composite was calculated using our result and compared with characteristic values measured in liquid phase. Various properties of carbon nanotube samples were determined to find the most appropriate one for biosensor application.

> **Applied research for hydrocarbon industry.**
The biocomponent ratio in liquid fuels as well as the usage of renewable resources need to be investigated in the fuel consumption of transport sector, as a result of EU directive 2003/30/EC. In this study, a high throughput sample preparation and measurement method was developed based on AMS measurement. Using radiocarbon measurements, it could be relatively simple and fast to measure the weight percentage of the fossil and biological sources by accelerator mass spectrometry (AMS). The method is applicable to determine the biogenic component derived proportions of fuel blends with high precision for mixing rates of liquid diesel fuels (0.5-100% biofuel content). Small quantity (4-5 mg) of the samples was dropped onto MnO_2 powder in a borosilicate glass combustion tube then evacuated by vacuum pump to $5 \cdot 10^{-3}$ mbar and flame sealed. Finally, all of the sealed tube samples were combusted at 550 ºC, and a compact vacuum line was used to quantitatively extract and purify the CO_2 from the combusted samples. The purified CO_2 samples were graphitized and their $^{14}C/^{12}C$ ratio was measured by a MICADAS AMS. Several parallel repetitions were prepared and measured to examine the reproducibility of the method and standards were also prepared along with the samples for quality control and chemical blank investigation.

INFRA-STRUCTURE

INFRASTRUCTURE

INFRASTRUCTURE

Life in the laboratory
(clumped isotope
thermometry laboratory)

The main aim of the ICER project is to study the past and present-day geo-, hydro- and biosphere and the complex climate to understand better the past and present-day effects and their application to climate change.

The research topics (projects) within the ICER project will be performed using already existing research infrastructure/ instruments, which are supplemented with the newly purchased state-of-art instruments: the multicollector inductively coupled plasma mass spectrometer and the clumped isotope mass spectrometer. These instruments have not been used previously in scientific or industrial research either in Hungary or in eastern Europe.

The state-of-art research infrastructure and our community of experienced researchers provide the opportunity to undertake several basic and applied research topics within the frame of the project. Some examples are the clumped isotope thermometry in paleoclimatology research, exposure age dating of rock surfaces using in-situ produced cosmogenic ^{14}C nuclide to understand better the past glacier movements and the high-resolution measurements of the fossilized carbon-load of the atmosphere.

INFRASTRUCTURE

MULTICOLLECTOR INDUCTIVELY COUPLED PLASMA ION SOURCE MASS SPECTROMETER (MC-ICPMS)

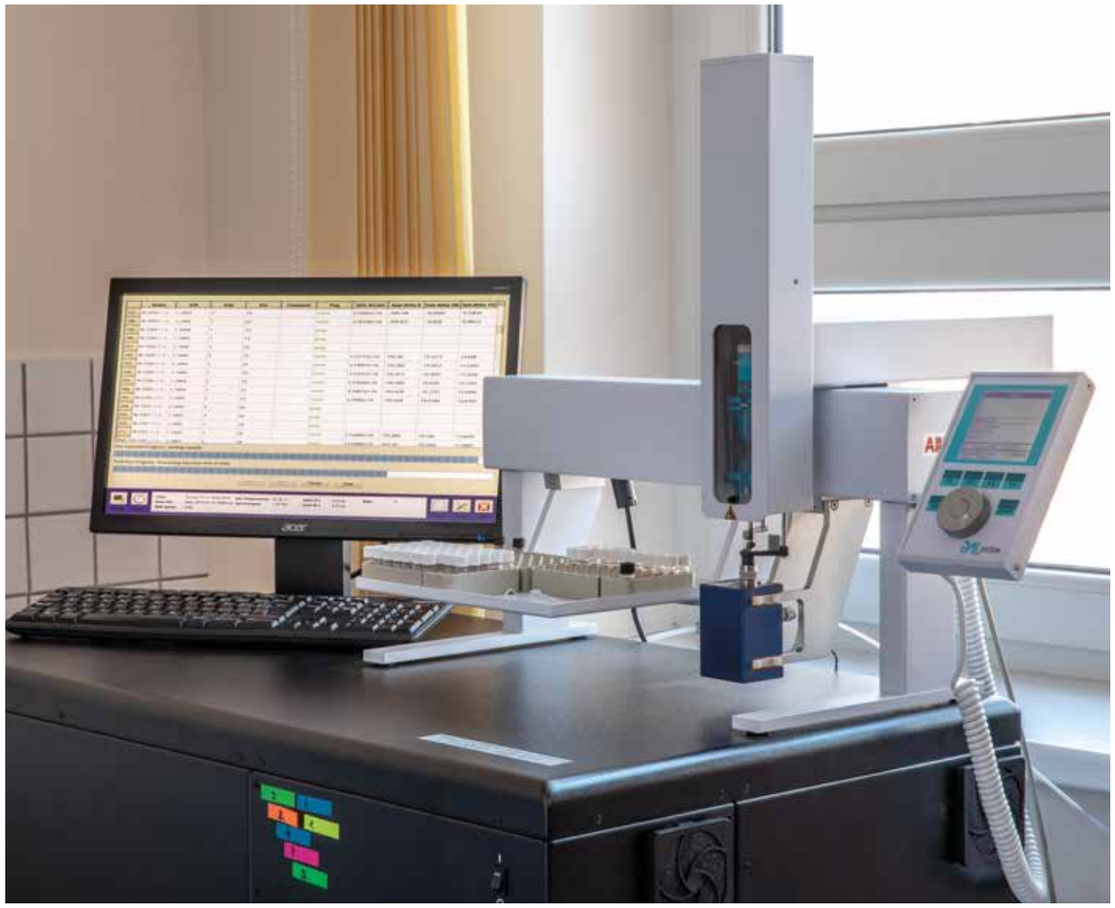
A Neptune Plus MC-ICPMS has been installed. For the first time in Hungary, which will strongly contribute to the determination of non-conventional isotope ratios with epsilon precision so that state-of-the-art research is performed. Primarily $^{234}U/^{230}Th$ age determination of carbonates will be performed, as well as $^{87}Sr/^{86}Sr$ isotope ratios of rock, groundwater and archaeologic samples (e.g. bone, finding). For geochemical research iron ($^{56}Fe/^{54}Fe$), copper ($^{65}Cu/^{63}Cu$) as well as $^{30,29}Si/^{28}Si$ isotope ratios will be also applied using the MC-ICPMS and the clean laboratory of Class 1000.

Neptune Plus
multicollector ICPMS

LOSGATOS SPECTROMETER

Two laser based Liquid Water Isotope Analyzers were installed, which are suitable for measuring δ^2H, $\delta^{18}O$ and $\delta^{17}O$ of water samples. The instruments operate on the principle of laser based absorption spectroscopy, which is an accurate optical absorption method for measuring isotopologues ($H_2{}^{16}O$, $H_2{}^{17}O$, $H_2{}^{18}O$, H_2HO) in a single gas matrix.

LGR cavity enhanced
infrared spectrometer for
water stable isotopes



TWO PICARRO CAVITY RING-DOWN SPECTROSCOPY ANALYSERS (CRDS)

Two Picarro Cavity Ring-Down Spectroscopy (CRDS) analysers installed at ICER Centre for Real-Time Atmospheric Monitoring of Stable Isotopes and Trace Greenhouse Gases as CO_2 and CH_4.

The **Picarro G2201-i Analyzer** combines capabilities of two carbon isotope instruments for CO_2 and CH_4into a single instrument. Using this instrument researchers can follow carbon as it moves from source to sink with a single instrument. Its small size and robustness make it easy to transport to the field, where immediate results allow researchers to change course on-the-fly and achieve optimal results from limited-time field campaigns.

Picarro cavity enhanced infrared spectrometer for CO_2-CH_4 carbon stable isotope ratios

MAT253 PLUS MASS SPECTROMETER

A Thermo Fisher Scientific MAT253 Plus type isotope ratio mass spectrometer and a Thermo Fisher Scientific KIEL IV automatized carbonate device is under installation in the ICER. This system is suitable for measurement of traditional carbon and oxygen isotope ratio of low weight carbonate samples down to 20 µg. Besides that the carbonate clumped isotope thermometry will be the main use and research field of this dedicated system in our laboratory.

The clumped isotope method is going to be used on various type of carbonates (fresh water carbonate deposits, biogenic carbonates, fossil otoliths) for the purpose of past climate parameter reconstruction.

MAT 253 Plus high resolution stable isotope ratio mass spectrometer and Kiel IV automatic carbonate extraction device

EXISTING (ALREADY INSTALLED) INFRASTRUCTURAL INSTRUMENTS

EnvironMICADAS AMS and sample preparation laboratory for ^{14}C analyses

Gas proportional counting system (GPC)

Fisons VG-5400 noble gas mass spectrometer

Thermo Finnigan Deltaplus XP isotope ratio mass spectrometer (IRMS)

Low-backround gamma- and beta-spectrometry laboratory

Inductively coupled plasma mass spectrometry (LA-ICP-MS)

INSTRUMENTS AND EQUIPMENT UNDER ACQUISITION

- C100/ISO5 clean laboratory
- Large-volume aerosol sampling tool/equipment for ^{14}C and isotope analytical measurements
- Instrument for preparation of dissolved organic carbon in water for ^{14}C measurements
- Rock preparation instrument for in-situ ^{14}C measurements
- Instrument/equipment for tree ring preparation
- Proportional counter tube for ^{39}Ar measurements
- Preparation line for bottled- air to measure ^{14}C from trace gases
- Polarizing microscope and its supplementary units

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EVENTS

EVENTS

^{39}Ar AGE DATING OF DRINKING WATERS IN SOUTH AFRICA

Our project has reached a new milestone with applying the membrane contactor sampling system that is able to extract a huge amount of dissolved gases from groundwater in a sampling field trip. In October 2019, 18 boreholes in South Africa were sampled with this sampling system in order to collect gas samples for age determination with ^{39}Ar and ^{85}Kr.

One half of the sampled boreholes are situated near Cape Town, Western Cape, South Africa. Considering the severe water shortage most notably affecting Cape Town, it is important to increase our knowledge of the area, since this is an important fresh water source. The other half of the samples was collected in Northern Cape (Buffels River Valley).

This arid region is strongly affected by salinization primarily driven by evaporative processes resulting in variably saline groundwater. The phenomenon is not fully understood yet, but it is evident that salinisation through evaporation is not the only driver in this regional system. That is why further investigation including our contribution is necessary.

PALEOCLIMATE RECONSTRUCTION OF THE AMAZON RAINFOREST IN ECUADOR BASED ON SPELEOTHEMS AND TREE RINGS

The short duration and scarcity of continuous instrumental climate records makes the reconstruction of the past climate very limited in Ecuador.

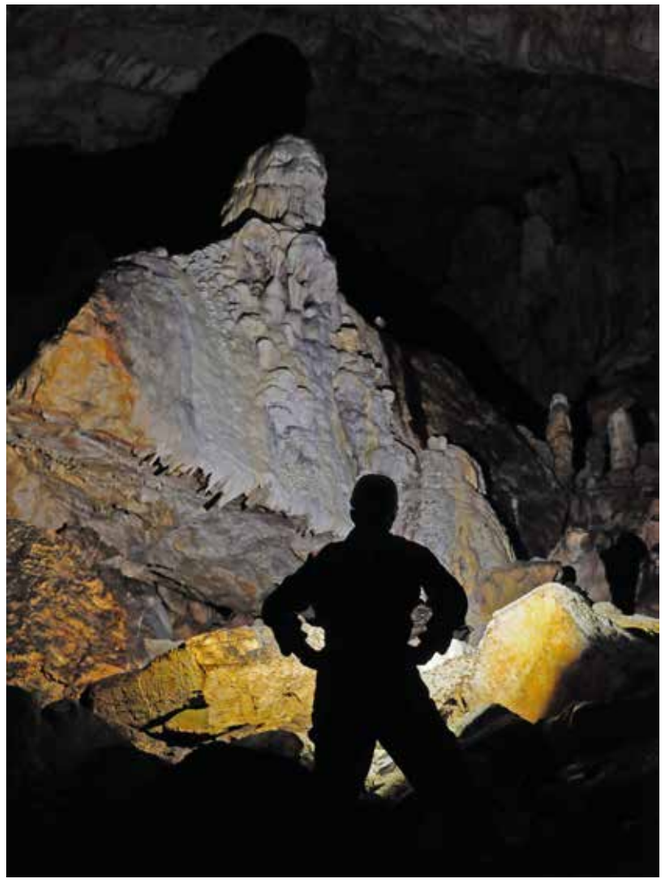
In this framework, the south-eastern karst areas of Mera, Pastaza provides the access to several caves with suitable stalagmites for paleoclimate studies. In addition, temperature loggers and rainwater collectors were installed in the area for stable isotope monitoring. With regard to biological aspects, the use of bat guano as seed dispersers for explaining flora underground diversity was carried out in the cave.

The exploration brought about the opportunity to complement our paleoclimate record in Mera. Thereby, in collaboration with Salesian Polytechnic University (UPS-Quito), tree cores were selected for dendrochronological studies to reconstruct tropical climate variability and detection of more frequent extreme climate events.

SPELEOTHEM-BASED PALEOCLIMATE STUDY AND INSTALLATION OF PRECIPITATION COLLECTORS IN KARST AREAS IN MACEDONIA

The drainage basin of Crna Reka, in the southern parts of Macedonia, is an area with complex and long geological evolution, hosting both hypogene and epigene karst.

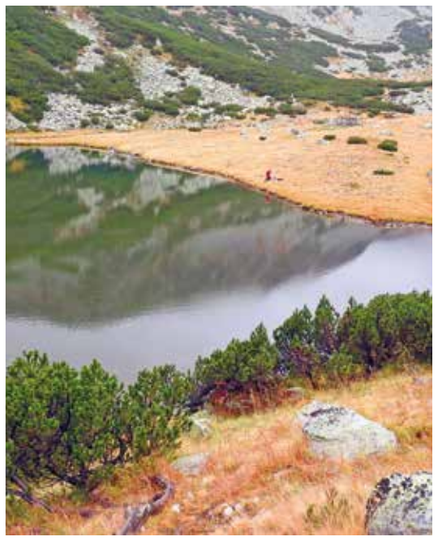
In this area we are conducting geochemical research on cave deposits and karst springs, and have recently selected few caves as possible speleothem study sites. One of them is Drenska Peštera, an old cave rich in speleothems, which we recently visited to check its suitability for a speleothem-based paleoclimate study. As there is almost no data on isotope composition of precipitation in Macedonia, during this field trip we have also installed four precipitation collectors at different locations and elevations, to monitor the isotopic composition of the precipitation water. This data will complement our speleothem-based paleoclimatological study, as well as our geochemical study of the karst springs in the area. This field trip, in collaboration with SK Zlatovrv from Prilep, provided the chance for one of our PhD students to get a basic training in caving techniques.



WATER SAMPLING AS A PART OF PALEOECOLOGICAL STUDY OF HIGH MOUNTAIN LAKES IN THE RETEZAT MOUNTAINS

Our knowledge of environmental parameters of glacial lakes and particulars of geochemical cycles of their elements is not sufficient.

The aim of this investigation as a part of paleoecological study of high mountain lakes in the Retezat Mountains (Southern Carpathians) is to reveal the features and dynamics of water quality and sediment chemistry. This investigation helps the understanding how these lakes has reacted to climate change and human effects so far.



GROUNDWATER SAMPLING IN MOROCCO

To reconstruct the former temperature conditions of North-West Africa, we visited Morocco to sample groundwater from the Turonian aquifer in the Tadla basin.

This type of climate reconstruction can be usable for the last few thousand years and it requires a complex paleo-hydrological study of the water body, based on the determination of the mean residence time of the water and the recharge temperature derived from dissolved noble gases.

GROUNDWATER SAMPLING IN BULGARIA

We were taking groundwater samples from a multi-layered aquifer system in the Lom depression of Danubian Plain in Bulgaria to find palaeowaters. Our aim is to model the past climate outside the Carpathian region.

In the field we can determine the general water chemistry parameters (temperature, pH, conductivity, redox potential, bicarbonate, calcium content) of the samples. In addition to the amount of anions and cations, in the laboratory we can measure the stable carbon, hydrogen and oxygen isotope ratio, noble gas concentration and tritium and radiocarbon content. As an isotope climatological research centre, we can determine the origin, recharge temperature, and age of the groundwater from the obtained results.

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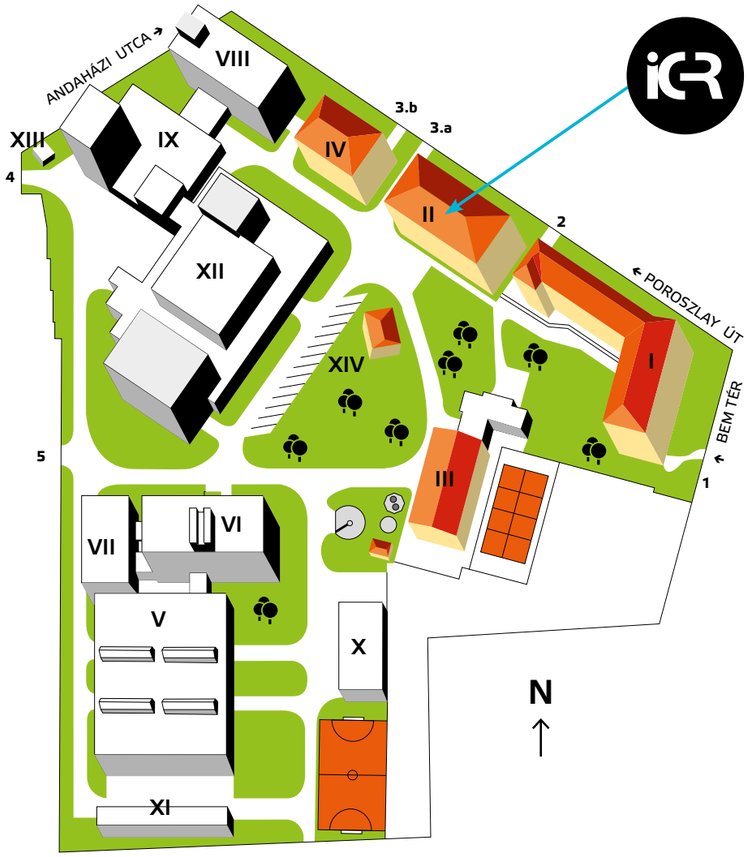

IMPRINT

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