International Symposium on Geofluids

7-9 July 2021
Virtual event

ABSTRACT VOLUME

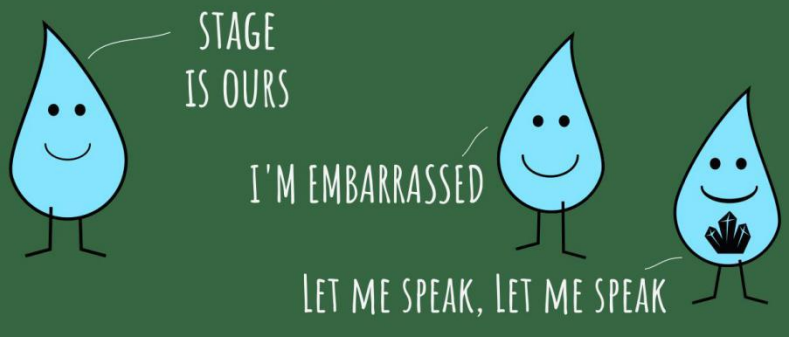
Organized by:

ENeRAG H2020 project*

József & Erzsébet Tóth
Endowed Hydrogeology Chair Foundation

ELTE
Eötvös Loránd University

geofluids2021.hu



* ENeRAG project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 810980

International Symposium on Geofluids

In memoriam of Erzsébet Tóth, co-founder of József and Erzsébet Tóth Hydrogeology Chair Foundation

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7-9 July 2021 – virtual event

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International Association of Hydrogeologists, Hungarian National Chapter and Commission on Managing Aquifer Recharge

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Geological Survey of Finland

Hydrogeology Subcommittee of the Hungarian Academy of Sciences

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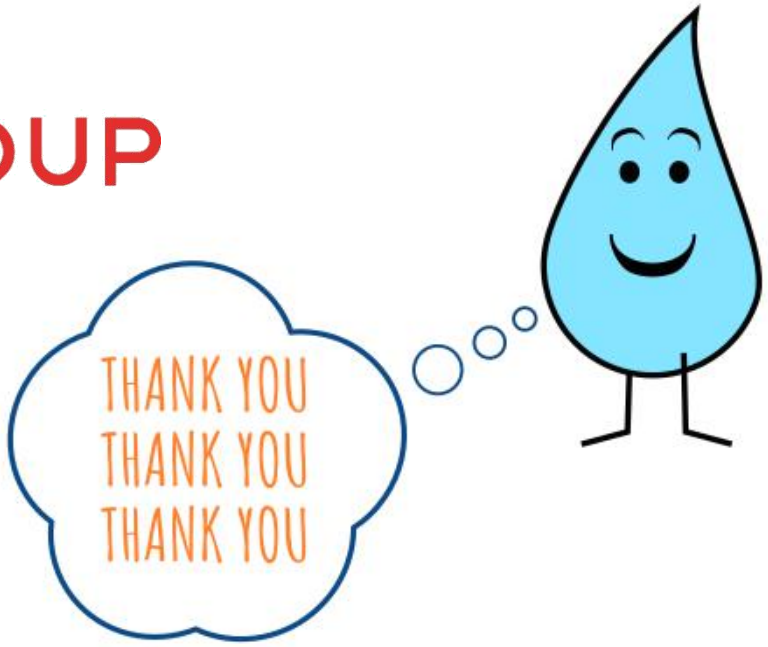

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ISBN978-615-81297-2-5

Publisher:
József and Erzsébet Tóth Hydrogeology Chair Foundation

József & Erzsébet Tóth
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Welcome note of Katalin Enikő Magyari

Dear Colleagues, Ladies and Gentlemen,

ELTE is the largest university in Hungary. With its 8 (and from 1st August 9) faculties, 52 bachelor, 112 master programs and 104 English master programs ELTE offers the widest range of higher education majors in Hungary. As for research reputation, ELTE has the highest number of academics in Hungary: 72. The most prestigious research grant for young talents in Hungary is the Momentum Grant that is the national sister of the European Research Council (ERC) Grants. 25 Momentum research groups operate and we have an increasing number of ERC Research groups, currently 7.

ELTE's popularity is well reflected in the applications. Every 4th student chooses ELTE at first place when applying for higher education in Hungary; every 5th PhD student performs his/her research at ELTE, and the total number of undergraduate and graduate students exceeds 33,300.

ELTE also performs well in European Union Grant applications. Currently 24 H2020, and 44 other EU projects (e.g. JUST, COST, INTERREG, Erasmus+) run at ELTE.

International conferences are also very important for the university, they provide an opportunity to enhance the university's reputation and showcase its excellence. The Scientific Council of ELTE announces a call for proposals for the organization of an international conferences at ELTE each year, and via this call supports 3-5 conferences per year. Budapest and the conference venues offered by ELTE are very popular, on average ELTE organizes 70-90 international conferences per year. International networking is taking place through the European University Alliance CHARM-EU. The Challenge-driven, Accessible, Research-based, Mobile European University alliance was called into being under the auspices of European Universities Initiative. It entered a new phase of its operation this year with the launch of the TORCH (Transforming Open Responsible Research and Innovation through CHARM) project. The objective of TORCH is to develop a research and innovation strategy for the alliance shaped by the five research universities. Within this project, ELTE is responsible for the leadership of the Open Science and the Pilot work packages.

ENERAG is the first twinning project hosted by ELTE that is fully funded by the European Union's Horizon 2020 research and innovation program. Institutional networking is a key element of this project that also meets the aim of the university to increase the number of EU networking grafts and bring in know-how from more developed European Union member partners.

I hope the participants will enjoy the conference and will broaden their knowledge by the end of the conference! WISHING you a fruitful meeting on behalf of the rector's leadership.

Prof. Katalin Enikő Magyari

vice-rector for research
Eötvös Loránd University
Budapest, Hungary

Welcome note of Imre Kacskovics

Dear Colleagues, Ladies and Gentlemen,

As the representative of the Faculty of Science, Eötvös Loránd University, it is my pleasure to welcome the attendees of the International Symposium on Geofluids. The event's main organizer, the ELTE, looks back at many long-standing traditions and provides the alma mater for several Nobel laureates and leading figures in technology, public policy, culture and science, such as János Neumann, Ignác Semmelweis or Albert Szent-Györgyi.

Besides preserving the values of 386 years of tradition, our main goal is to maintain the highest standards in research and education, and to that end, we strive to meet the expectations of the 21st century. Our faculty has five institutes: Mathematics, Biology, Physics, Chemistry, the Institute of Geography and Earth Sciences, and the Center for Environmental Studies. One of the main strategic goals of the faculty is to increase the capacity, international networking, dissemination, research and innovation as well. In the meantime, we intend to gain resources provided nationally and by the EU in order to keep and further improve our position in the rank of universities.

We have several promising and well-recognized research groups in the faculty that carry out their research with strong international background and the stakeholders' active cooperation. Groups like these are the key elements of solving current and future emerging environmental issues, and they contribute to a successful social adaptation to the new challenges.

The hydrogeology group operating within the Institute of Geography and Earth Sciences is one of these research groups. The group was created to promote the legacy of the world-famous Hungarian Professor, Joe Tóth, also referred to as Mr Hydrogeology. His regional groundwater flow theory and its applicability are further developed by the hydrogeology group led by Judit Mádl-Szőnyi. Professor Tóth's foundation provides support to the group's research activities. As one of their latest achievements, the group won a Twinning project, ENeRAG, in the most competitive EU Horizon 2020 grants in cooperation with scientists from the Geological Survey of Finland and the University of Milan.

This geofluid symposium focuses on the main topic of the ENeRAG project and highlights the significance of the regional groundwater flow theory. The focus of interest is underground fluids. The significance is well-recognized, even for those coming from a different field of expertise, when one thinks of the value of groundwater, renewable energy resources and circular economy. I am positive that this conference will help create strong connections between scientists and stakeholders from all over the world.

It is my pleasure that the faculty can support the successful execution of this symposium.

I am hopeful that this Symposium will help the faculty and the institute reach the goal of creating an Excellence Center for Geofluids here at the ELTE, which also represents the final goal of the ENeRAG project. In the end, I wish all of you a successful symposium with many great presentations, constructive discussions and new collaborations.

Imre Kacskovics

Dean of the Faculty of Science at the Eötvös Loránd University
Budapest, Hungary

Welcome note of Teodóra Szőcs

Ladies and Gentlemen, Dear Colleagues, Members of the Organising Committee, Session Chairs, and Presenters!

I would like to welcome all of you to the International Symposium on Geofluids to this long-awaited, three day, online event.

The Regional Groundwater Flow Commission (RGFC) of IAH with Judit Mádl-Szőnyi as its chair has been actively involved in the organization of this event. The RGFC is one of the most active commissions of IAH with a wide range of activities. It fosters international research and practical application of groundwater flow systems, focusing on the relevance of, and consequences to the regional groundwater flow. Mathematical analysis of the properties of flow systems, as well as field- and GIS-based methods are all part of the studies undertaken to understand how regional groundwater flow acts as a geological agent. It also aims to increase our knowledge of the interlinkage between the basin-scale gravitational groundwater flow systems and geothermics, mineral exploration, petroleum exploration and several other disciplines. This event is an expression of the excellent collaboration between the IAH Commissions and it is my great pleasure to welcome the IAH Commission on Managing Aquifer Recharge as a supporter. This Symposium is a good example of how we can combine the elements of the different studies and develop a synergy through the shared results.

As I have mentioned, this is a long-awaited event, and just as with other congresses, conferences and meetings this also had to be postponed from 2020 to this year due to the COVID-19 pandemic. During the last two years our way of working and interacting with other colleagues has been changed completely, with field studies and analytical or laboratory work reduced or delayed, as well as face to face meetings cancelled or changed to online events. Unfortunately, while most of us prefer face to face events, we have no choice except to meet in a virtual space during these 3 days.

As you are all aware, the key aim of this Symposium is to provide a platform to discuss the different aspects of geofluids where students, early career and senior professionals, and stakeholders can share their research experience.

The main symposium topics are grouped in five sessions:

- Energy flow systems, related fluids and their simulations
- Managed aquifer recharge, adaptation to climate change and ecohydrology
- Geoenergy, thermal water and hydrocarbon systems
- Natural and anthropogenic contamination, vulnerability and hazards of geofluids
- Fluid-rock interaction and hydrogeochemical processes

The presentations will provide an opportunity to discuss and better understand flow systems, geothermal energy, thermal water and hydrocarbon systems, geogenic contamination and hydrothermal mineral resources for example. Due to climate change, climate adaptation strategies are needed more widely, not only in arid or semi-arid regions to facilitate a sustainable (ground)water management. Application of managed aquifer recharge methods can facilitate this which is one of the themes of the ENeRAG project and therefore of this Symposium, too. Fluid-rock interactions and hydrogeochemical reactions are often challenging to understand or to predict along flow paths, which will be also addressed. In addition to the assessment of groundwater, the symposium will look at geofluids, the harmonized exploration and utilization possibilities

of groundwater and geofluids. The Symposium provides an opportunity to discuss the scientific results also with decision makers and stakeholders.

The 5 keynote lectures given by leading international experts, the 40 oral and 28 poster presentations, and participants from 25 countries ensure that this international symposium will have a major impact in the expanding fields of hydrogeology. In addition to all the oral and poster presentations, there is a virtual banquet, Budapest sightseeing, and cooking experience which will make the Symposium not just scientifically interesting but will allow us to socialise and relax.

Although these are my welcome notes at this opening ceremony, some of you have already taken part in the pre-symposium short courses held on the 5th and 6th of July. On the 5th the topic was the "Hydrochemical modelling with PHREEQC and its application of fluid-rock interaction" given by Vincent Post from the Federal Institute of Geosciences and Natural Resources (BGR), Hannover, Germany and on the 6th of July the topic was the "Numerical simulation of groundwater flow and heat transport processes" given by John W. Molson from the Université Laval, Quebec City, Canada.

A big thank you to Judit Mádl-Szőnyi for organizing this Symposium in spite of all the unknowns and uncertainties caused by the COVID-19 pandemic, for the keynote lecturers for accepting the invitation, for all participants who signed up to take part in this event and of course to the whole organizing committee who worked in the background and made this virtual event a reality. I wish all of you a successful and fruitful event and I hope we can meet with many of you in person at the IAH 48th Congress in Brussels between 6-10 September 2021.

Teodóra Szőcs

IAH VP for Finance and membership
Mining and Geological Survey of Hungary

Welcome note of Marco Masetti

Distinguished Participants, Ladies and Gentlemen, Dear friends and colleagues,

hello and welcome to the Geofluids Symposium, where we will explore many important themes related to geofluids use and management that are within the political Agendas of many Nations and International Organizations and Associations.

As a hydrogeologist, I have a natural interest in water and in your travel through the five oral and poster sessions you will come across multiple interests related to water resources such as energy production, water quality and quantity, ecosystem maintenance, solutions to cope with climate change effects.

The development of studies and researches on these themes is crucial to reach many of the Sustainable Development Goals (SDGs) established by the United Nations for year 2030. In many areas of Europe and the World, current trends in water quantity and quality are undermining progresses towards many SDGs, such as Poverty, Hunger, Health, Clean Energy, Cities, Responsible Consumption and Production, Climate, Life below Water and on Land.

According to the Global Risk Report 2020, water crises are one of the most important risks to the economy and society in the coming years: by 2025, two thirds of the global population could be facing water stress, global water requirements are projected to push beyond sustainable water supplies by 40% by 2030, with global use doubling by 2060, around 80% of wastewater is discharged untreated, agricultural use accounts for 70% of water use worldwide, energy production will lead to an 85% increase in water demands by 2035.

All these risks highlight how water, as the most relevant geofluid on the Earth, is an essential asset also for achieving the European Green Deal in many of its policy components. Biodiversity, Sustainable agriculture, Clean energy, Sustainable industry, Eliminating pollution and Climate action require the promotion of innovative technologies, management practices and governance models that should be applied and shared to achieve a better and more sustainable future for all.

I am confident that you will find new ideas, fresh energy and novel partnerships to sustain your efforts in support new studies and researches in Geofluids systems and use through science, technology and innovation.

I wish you all a very successful Symposium, and now, let’s rock together towards new projects and opportunities!

Marco Masetti

Dipartimento di Scienze della Terra,
Università degli Studi di Milano, Milan, Italy

Welcome note of Ferenc Molnár

Dear Colleagues,

As the representative of the Geological Survey of Finland, I intend to talk about the significance of geofluids in the European research and innovation and the ENeRAG project connecting the GTK and ELTE, the host institute of this Symposium.

The professional background of the ENeRAG project is based on that formation and usability of significant geological resources such as groundwater, hydrocarbons, geothermal energy and hydrothermal mineral deposits can be related to the interaction of fluid systems with various lithological units at different levels and tectonic settings in the Earth`s crust. These geological resources represent some of the fundamental pillars for the socio-economic development of the European Union. Supporting cooperative research and innovation projects aiming to develop sustainable use of geological resources is in the focus of various Horizon 2020 programmes and forthcoming Horizon Europe programmes.

At the Geological Survey of Finland (Geologian Tustkimuskeskus – GTK), the majority of research and development projects co-funded by the European Union address the key challenges related to the use of geological resources by providing scientific results and innovations. GTK has been the leader and participant of large number of EU-funded projects during the past years. These projects are always built up on the innovative international network of geological surveys, universities and companies. The achievement of the goals of these projects requires continuous capacity building which includes development of scientific expertise, development and maintaining high quality partnerships with the academy and industry and increase of the use of scientific competence in finding solutions for societal challenges. The ENeRAG project is based on the cooperation between GTK, the Eötvös Loránd University and the University of Milan and aims to develop an excellency network for research and assessments of geofluid systems. Therefore, it is in line of the major strategic interests of the Geological Survey of Finland. Nowadays GTK considers the ENeRAG project as a model of similar EU-supported twinning and excellency development projects.

One of the major events of the ENeRAG project is the current International Symposium on Geofluids. The five sessions of the symposium and the pre-conference short courses provide the state-of-art reviews of various aspects of geological and geochemical peculiarities and modelling in geofluids systems. In addition to the scientific merits, this symposium also aims to enhance discussions not only among the partners of the ENeRAG project but to trigger development of research and innovation networks among the participants from other academic and industry organizations.

Ferenc Molnár

research professor
Geological Survey of Finland

Welcome note of Judit Mádl-Szőnyi

Dear Colleagues,

I am honoured to welcome you on behalf of the organizers at the virtual "International Symposium on Geofluids".

Significant geological resources were formed due to the interaction between fluids of different nature and the rocks forming the Earth crust. Research on geofluids has been evolving since the 1980s. Since then, fluid geology has been gaining increasing attention compared to traditional solid geology. We need, however, to advance our understanding on fluid-rock-related processes, on different geofluids and their interrelationship. For this reason, emphasis should be put on the dynamics of the fluid flow systems and the geological effects of fluids in the lithosphere. This is the focus of this Symposium.

Geofluid Symposium provides a platform for academic discussion among the ore and petroleum geologists, and experts on groundwater and geothermal fluids. It also aims to initiate the conversation between experts to understand each other's research context, research trends and to establish a more common language. In addition, declared objective of the Symposium is to bring together scientists, professionals, and stakeholders to share and discuss all kinds of topics on geofluids. This may contribute to finding the most appropriate approach in resolving issues related to geothermal energy, hydrocarbon, geogenic and anthropogenic contamination, hydrothermal mineral resources. Special emphasis will be placed on geofluid assessment tools and methods, harmonized exploration, and sustainable utilization of the different resources. We are, therefore, happy to welcome researchers dealing with various aspects of geofluids research.

The Eötvös Loránd University (ELTE) organizes the Symposium within the frame of the ENeRAG H2020 project, titled as Excellency Network Building for Comprehensive Research and Assessment of Geofluids. We are grateful to the partners and colleagues from the Geological Survey of Finland and the University of Milan for this fruitful collaboration.

Here I would like to thank the support of the József and Erzsébet Tóth Endowed Hydrogeology Chair Foundation of ELTE. The Symposium is dedicated to the memory of Erzsébet Tóth, who was one of the co-founders of the organization. I am thankful to the Regional Groundwater Flow and the Managed Aquifer Recharge Commissions, as well as to the Hungarian National Chapter of the International Association of Hydrogeologists. In addition, I would also like to thank the support of the Hydrogeological Sub-commission of the Hungarian Academy of Sciences.

Special thanks to the media partner of the Symposium, the Water MDPI Journal, for providing the platform for publications, as outcomes of this event, in a Special Issue.

The financial support of the Faculty of Science of ELTE, the European Union through the ENeRAG H2020 grant and the MOL Group, the Hungarian Oil and Gas Company as the main supporter of the Symposium are greatly appreciated.

I am thankful to the Diamond Congress, the Organizing and the Scientific Committee members for the hard work they did in the last year. After a year of postponement of the Symposium, I am immensely proud that finally, we could organize this online event.

On behalf of the Organizers, I wish all of us a successful Symposium.

Judit Mádl-Szőnyi

Chair of the Symposium
Chair of the IAH Regional Groundwater Flow Commission
József and Erzsébet Tóth Hydrogeology Chair

Department of Geology
Eötvös Loránd University
Budapest, Hungary

Members of the Honorary Committee

József Tóth

University of Alberta, Edmonton, Canada

Professor József Tóth is a world-known geophysicist, the “father of modern hydrogeology”. His name is associated with hydrogeology's fundamental concept, also called the “Tothian flow system theory”. He was continuously developing the theory of gravity-driven flow system as a fundamental geologic agent, with practical and economic interest, while working and teaching around the world from India, China as far as Australia and Mexico. He spent most of his scientific life in Canada and he became involved in Hungarian hydrogeology from the early 1990s. To name but a few among his awards: his 1963 paper won the “O.E. Meinzer Award”, IAH chose him for their “1999 President’s Award”, “Robert N. Farvolden Award” in 2002, “M. King Hubbert Award” in 2003, “C.V. Theis Award” in 2004, IAH’s “Award of Honorary Membership” in 2012. His textbook “Gravitational Systems of Groundwater Flow” as his “scientific autobiography” was published in 2009. He is a lifetime Honorary Chair of the Regional Groundwater Flow Commission of IAH from 2011. He founded the “József and Erzsébet Tóth Hydrogeology Chair Foundation” for the purpose to improve the state and position of Hungarian hydrogeology, assisting the research and education of hydrogeology in Hungary and fostering national and international relations.

Ladislaus Rybach

Swiss Federal Institute of Technology (ETH), Zurich, Switzerland

Ladislaus Rybach is a worldwide known expert and lecturer. His research extends from general geothermics over sustainability issues to the application (geothermal heat pump systems and EGS/HDR modelling). He was chairman (1997-2004) and vice-chairman (2002-2009) of the IEA Geothermal Implementing Agreement Executive Committee, co-founder and managing director (2002-2011) of the ETH Spin-off company GEOWATT AG, vice president (2001-2004) and president (2007-2010) of the International Geothermal Association (IGA). He is Honorary Guest of the University of Zurich, Foreign Member of the Hungarian Academy of Sciences, Honorary Member of the Hungarian Geophysical Association, recipient of the Patricius Medal of the German Geothermal Society, of the Japanese Government Research Award, of the IGA International Summer School Award, of the Unione Geotermica Italiana Honorary Award, of the GRC Henry Ramey Geothermal Reservoir Engineering Award, and the GRC Geothermal Special Achievement Award. He is an Honorary Professor of the Technical University of Oradea/Romania and an honorary doctor and professor of the Eötvös Loránd University Budapest, Hungary.

Imre Müller

University of Neuchâtel, Neuchâtel, Switzerland

Imre Müller was born in Hungary. He attended the primary and secondary schools in Budapest (Hungary). He completed his Bachelor degree in Philosophy and Theology at the Institut Catholique de Paris (France), he graduated from the University of Fribourg (Switzerland) as lic. rer. nat., followed by completing his PhD degree in Geology at the same university. He completed a post-graduate course on hydrogeology at the University of Neuchatel (Switzerland). He became Lecturer and, later, Professor of Applied Hydrogeology for graduate and postgraduate students at the Centre Hydrogeologie (University of Neuchatel). His main research areas are surface geophysics (electromagnetics), tracer technics applied for karst water prospection and protection. He became Visiting and, later, Honorary Professor at the Eötvös Lóránd University (ELTE) in Hungary. He is the UNESCO Chair-holder at the Erdélyi Mihály School of Advanced Hydrogeology (ELTE). He is an Honorary Professor at the Pannon University (Veszprém, Hungary) and at the West-Hungarian University (Sopron), as well as a Guest Professor at the Albert-Ludwig University (Freiburg in Br., Germany).

Renquan Zhang

China University of Geosciences, Wuhan, China

Professor Zhang Renquan born in 1932 and graduated from Northeast College of Geology in 1953 major in geology and mineral resources survey. He completed his post-graduate studies in hydrogeology at Beijing College of Geology in 1956, supervised by a Soviet professor M. M Krylov. He founded the research group of Gravitational Groundwater Flow Systems at China University of Geosciences in the 1980s which has been active by him and his colleagues until now. Professor Zhang authored and co-authored several books and many papers on groundwater flow systems. He has been the second author (versions 1-5) or first author (versions 6-7) of the Chinese textbook titled “Fundamentals of Hydrogeology”. He is the second author of the Chinese monograph titled “Groundwater Flow Systems: Theory, Application and Investigation” and the first editor of Chinese translation of “Gravitational Systems of Groundwater Flow: Theory, Evaluation, Utilization” written by József Tóth.

Heinz Surbeck

CEO Nucfilm GmbH, Cordast, Switzerland

Dr. Heinz Surbeck is a physicist, who is interested in groundwater-related issues. He used to work for the University of Neuchatel and ETH Zurich (Switzerland). Now he is working for his own small company, Nucfilm.

One of his major research fields is environmental radioactivity, and the use of naturally present radionuclides as tracers and fingerprints in hydrogeology. As former head of the Swiss Federal Environmental Radioactivity Lab, he is also dealing with the health impact of natural radionuclides.

Dr. Surbeck is also an exceptionally talented inventor. The selectively adsorbing uranium and radium discs, and many useful field and lab measuring devices are connected to his devotion to science.

Jim LaMoreaux

PE LaMoreaux & Assocs., Inc., United States of America

Dr. James W. LaMoreaux is the chairman of the Board of PELA GeoEnvironmental, Tuscaloosa, Alabama, USA. PELA GeoEnvironmental (www.pela.com) is an international consulting firm providing services in hydrogeology, geology, and environmental sciences. Dr. LaMoreaux also serves as President of the International Association of Hydrogeologists (IAH) US National Chapter, Chairman of the IAH Commission on Mineral and Thermal Water and a member of the IAH Karst Commission. He is Editor of Springer's international journals: Environmental Earth Sciences, Carbonates and Evaporites, Sustainable Water Resources Management, and Discover Water. He also serves as Editor of the Environmental Geology Volume of Springer's Encyclopedia of Science, Sustainability, and Technology and as Editor of several Springer book series (www.springer.com).

Dr. LaMoreaux has been a member of the Water Environment Federation (WEF) for over 30 years and served as President and State Director of the Alabama Water Environment Association (AWEA). Additionally, he served on the Board of Directors of the American Ground Water Trust and on the Science Advisory Committee for the Urban Waste Management and Resources Center, funded by the US Environmental Protection Agency.

Scientific Committee

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Biography of the keynote speakers

Niels Hartog

Dr. Niels Hartog has over 20 years of professional scientific expertise in the fields of groundwater chemistry and environmental hydrogeology. He holds an MSc in Environmental Hydrogeology from the Vrije Universiteit Amsterdam (NL) and a PhD in Hydrogeochemistry from Utrecht University (NL). At KWR Water Research Institute (NL) he is the Principal Scientist for the Geohydrology team and a member of KWR's Scientific Council. Additionally, he holds a part-time position at Utrecht University as a Guest Associate Professor in the Environmental Hydrogeology group. He has supervised over 30 MSc and 10 PhD students and has (co-)authored over 40 articles peer-reviewed international journals on topics ranging from groundwater quality to managed aquifer recharge (MAR) and (geo)thermal production and storage (ATES). Since 2018 he is the president of the Netherlands National IAH Chapter and since 2019 the leader of the IAH Working Group on Urban MAR.

Inga Berre

Inga Berre is professor at the Department of Mathematics, University of Bergen. Her research interests are mathematical modelling, partial differential equations and numerical methods, in particular motivated by simulation of coupled thermo-hydro-mechanical-chemical processes in geothermal systems. She is the director of the Center for Modeling of Coupled Subsurface Dynamics and the principal investigator of the ERC Consolidator Grant: "Mathematical and Numerical Modelling of Process-Structure Interaction in Fractured Geothermal Systems" (2021-2026). Since 2018, she has chaired the Joint Program Geothermal, European Energy Research Alliance and since 2019 she has been co-chair of the SET-Plan Deep Geothermal Implementation Working Group. She is Associate Editor of Geothermal Energy (Springer). Inga Berre is member of the Norwegian Academy of Technological Sciences, chair of the SIAM GS activity group and member of the Interpore Program Committee.

Xiao-Wei Jiang

Xiao-Wei Jiang obtained his PhD in hydrogeology in the year 2011 and then became a Lecturer at China University of Geosciences (Beijing). He got promoted to an associate professor in 2013 and to a Professor in the year 2016. Currently he is the vice dean of School of Water Resources and Environment.
Since 2009, he conducted a series of studies on hydraulics and various influencing factors of gravitational groundwater flow systems, as well as identification of gravitational groundwater flow systems by using geophysical, hydrochemical and isotopic techniques. He published over 20 international papers and a Chinese book on gravitational groundwater flow systems. He taught such courses as hydraulics, groundwater hydraulics for undergraduates, and regional groundwater flow systems for graduates. He is a co-chair of the Regional Groundwater Flow Committee of IAH.

Daniele Pedretti

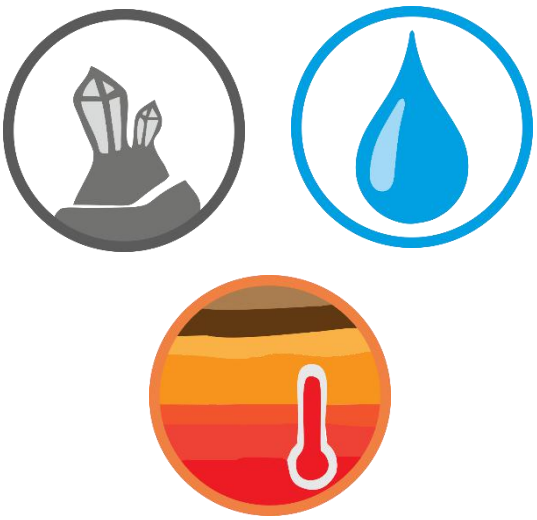
Daniele Pedretti is assistant professor of hydrogeology at the University of Milan, Italy (2019-present). His main research area is flow and reactive transport modelling in saturated and unsaturated geological media. He applies such models to managed aquifer recharge, mining acid rock drainage management, groundwater contamination by arsenic and organochlorides, and other strategic areas. Daniele was one of the developers of geological entropy (Bianchi and Pedretti 2017, 2018 WRR). In the past, Daniele was research professor in hydrogeology at the Geological Survey of Finland (2016-2019), and postdoctoral fellow at the University of British Columbia, Canada (2013-2016). Daniele obtained his doctorate title in Geosciences at the Technical University of Catalonia - Barcelona Tech, Spain (2012). Daniele's profile can be also seen: here.

Vincent Post

Vincent obtained a PhD degree in hydrogeology from the VU University in Amsterdam, the Netherlands in 2004. He worked as an assistant professor at this university from 2004 to 2010, and subsequently as a senior lecturer at Flinders University in Adelaide, Australia between 2010 and 2015. From 2016 to 2021 he was employed as a research associate at the Federal Institute for Geosciences and Natural Resources (BGR) in Hannover, Germany. His main expertise is on the fate of solutes in groundwater, in particular in coastal areas. He is one of the lead developers of the PHT3D code, a three-dimensional reactive transport simulator with capabilities for variable-density and unsaturated flow. He has conducted hydrogeological investigations in the Netherlands, Portugal, Australia, and the Pacific region. He was the lead author of a Nature article that was published in 2013 in which it was demonstrated that freshwater reserves under the seafloor are a global phenomenon. He served as an editor for Hydrogeology Journal between 2010 and 2015 and is the author of more than 80 refereed journal articles. His book "Coastal Hydrogeology", co-authored with Jimmy Jiao, was published by Cambridge University Press in 2019.

Main topics and sessions

1. Energy flow systems, groundwater flow systems, related fluids and their simulations
2. Managed aquifer recharge, adaptation to climate change and ecohydrology
3. Geoenergy, thermal water and hydrocarbon systems
4. Natural and anthropogenic contamination, vulnerability and hazards of geofluids
5. Fluid-rock interactions and hydrogeochemical reactions



Symposium program

Timing provided in CEST	Day 1	Day 2	Day 3
09:00-09:30	Opening ceremony		
09:30-10:00		Keynote 3	
10:00-10:15	Keynote 1	oral presentations	oral presentations
10:15-10:30			
10:30-10:45	oral presentations	workshop	
10:45-11:00			
11:00-11:15			
11:15-11:30			poster session
11:30-11:45			
11:45-12:00			
12:00-12:30	lunch	lunch	
12:30-13:00			lunch
13:00-13:15	oral presentations	Honorary lecture	
13:15-13:30			
13:30-13:45		oral presentations	Keynote 5
13:45-14:00			
14:00-14:15		poster session	oral presentations
14:15-14:30			
14:30-14:45			
14:45-15:00			break
15:00-15:15	break		
15:15-15:30			oral presentations
15:30-15:45	Keynote 2	break	
15:45-16:00			
16:00-16:15	oral presentations	Keynote 4	
16:15-16:30			Closing ceremony
16:30-16:45		oral presentations	
16:45-17:00			
17:00-17:15			
17:15-17:30			
17:30-17:45			
17:45-18:00			
18:00-18:30		Budapest sightseeing	
18:30-20:00	Banquet		

7 July

9:00 **OPENING CEREMONY**

Judit Déri-Takács (moderator): Welcome

<u>Opening of the symposium:</u>
- **Katalin Enikő Magyari**,
  Vice-rector for research, ELTE

<u>Welcome notes:</u>
- **Imre Kacskovics**,
  Dean of the Faculty of Science, ELTE
- **Teodóra Szőcs**,
  Vice-president, IAH
- **Marco Masetti**,
  UMIL
- **Ferenc Molnár**,
  GTK
- **Judit Mádl-Szőnyi**,
  Symposium chair, ELTE

<u>Technical information</u>
- **Attila Varga**
  Diamond Congress Ltd.

SESSION 1:
ENERGY FLOW SYSTEMS, RELATED FLUIDS AND THEIR SIMULATIONS

Chairs: Xiao-Wei JIANG | Brigitta CZAUNER

10:00	Keynote presentation by **Xiao-Wei JIANG** Recent progress in hydraulics and hydrochemistry of groundwater flow systems
10:30	**Andrew LOVE** Effect of basement leakage in contrast with the common no-flow base conditions in 2D Tóthian flow
10:45	**Zheming SHI** Aquifer system characterization by passive investigation method
11:00	**Yueqing XIE** Groundwater hydraulic and age responses to historical climate change in arid and semiarid regions with topography-driven flow
11:15	**Mária MOLNÁR** Transient numerical modelling for the karst aquifer of the Transdanubian Range between 1951-2030
11:30	**Samrit LUOMA** Groundwater flow models of the glacial aquifers at Lahti and Mikkeli sites, southern Finland
11:45	**Nina HENDRIKSSON** Tracing groundwater recharge using meteoric isotope signal of deuterium excess
12:00	**LUNCH BREAK**

SESSION 1
ENERGY FLOW SYSTEMS, RELATED FLUIDS AND THEIR SIMULATIONS (CTD.)

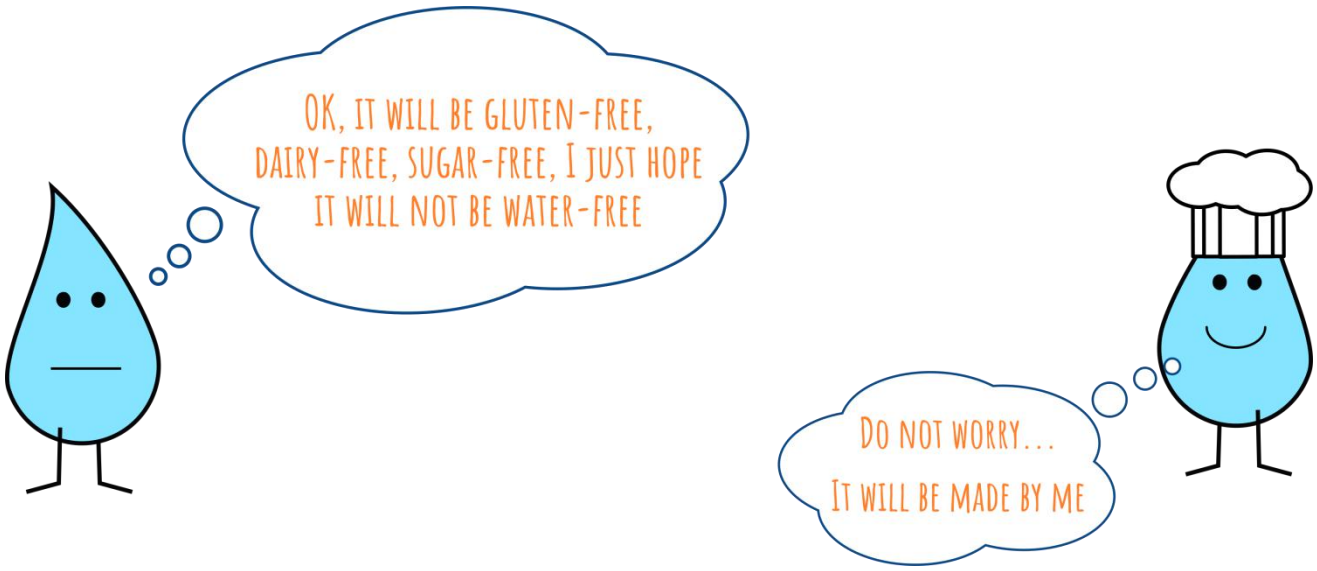
Chairs: John MOLSON | Hanneke VERWEIJ

13:00	**Márk SZIJÁRTÓ** Role of coupled fluid flow and heat transfer in synthetic and real groundwater flow systems
13:15	**Attila GALSA** Topohaline and Topothermohaline Convection in Regional Groundwater Flow Systems in Synthetic and Real Hydrogeological Environment
13:30	**Maja TODOROVIC** Hydrogeochemical characterization of the regional groundwater flow systems in Southern part of Pannonian Basin (Serbia)
13:45	**Alessia KACHADOURIAN MARRAS** The forgotten facts of the visibility of groundwater
14:00	**Ibtissem DJAAFRI** A hydrogeochemical study of thermal water (Geysers Hammam Debegh & Ouled Ali) using Toth's theory in Eastern Algeria
14:15	**Denisse DE LA FUENTE VIVANCO** Groundwater flow systems in Petorca River Basin, Chile: Their contribution to improve water management and protection
14:30	**Ibtissem YAHYAOUI** Groundwater discharge visibility and vertical flow in understanding recharge in western Tunisia
14:45	**Yussef ABUD RUSSELL** Identification of recharge and discharge zones in a gravity-driven regional groundwater flow. The case of the Yucatan Peninsula, Mexico
15:00	**COFFEE BREAK**

SESSION 2
MANAGED AQUIFER RECHARGE, ADAPTATION TO CLIMATE CHANGE AND ECOHYDROLOGY

Chairs: Niels HARTOG | Catalin STEFAN

15:30	Keynote presentation by **Niels HARTOG** Global water crisis: Managed Aquifer Recharge (MAR) to the Rescue?
16:00	**Kristiina NUOTTIMÄKI** Isotopic data in groundwater-surface water interaction study for a MAR site characterisation
16:15	**Catalin STEFAN** Modelling of managed aquifer recharge schemes in near-real time using the INOWAS web-based simulation platform: experiences from a WaterJPI research project
16:30	**Matej BLATNIK** Impact of flooding pattern changes and human activities on the ecohydrology of the Cerkniško Polje, Slovenia
16:45	**Zsóka SZABÓ** The Effectivity and Potential of Rooftop Rainwater Harvesting by Shallow Well Infiltration in Kerekegyháza, Hungary
17:00	**Ágnes ROTAR-SZALKAI** Suitability mapping of MAR schemes in Hungary
18:00	**BANQUET**



8 July

SESSION 3
GEOENERGY, THERMAL WATER AND HYDROCARBON SYSTEMS
Chairs: Hanneke VERWEIJ | Teppo AROLA

9:30	Keynote presentation by **Inga BERRE** Numerical modelling of fracture deformation and propagation in development and production of geothermal systems
10:00	**Yanlong KONG** Fault-affected fluid circulation revealed by hydrochemistry and isotopes in a large-scale utilized geothermal reservoir
10:15	**Francesco CECINATO** Energy efficiency of thermo-active micro-piles

10:30 **WORKSHOP ON GEOFLUIDS**

Judit MÁDL-SZŐNYI
What is the significance of incorporating flow systems in geofluid research? – Exchanging views from scientific basis to practical approach

Scientific moderators:
Brigitta CZAUNER, Ádám TÓTH, Judit DÉRI-TAKÁCS

12:00 **LUNCH BREAK**

SESSION 3
GEOENERGY, THERMAL WATER AND HYDROCARBON SYSTEMS (CTD.)
Chairs: Francesco CECINATO | Inga BERRE

13:00	Honorary lecture **Ladislaus RYBACH** Hydrogeochemistry of warm water inflows in deep tunneling – technical risks and geothermal chances. Examples from the Swiss Alps
13:30	**Ernst HUENGES** Hydraulic stimulation treatments in the geothermal injection well in Mezőberény, Hungary
13:45	**John MOLSON** Numerical simulation of fluid flow and thermal transport in the context of enhanced geothermal potential with discrete fracture networks in the St. Lawrence Lowlands basin, Quebec, Canada

14:00 **POSTER PRESENTATIONS**
Chairs: Catalin STEFAN | John MOLSON (2,5 min/presentation)

14:45 **POSTER DISCUSSION IN THE LOBBY**

15:30 **COFFEE BREAK**

SESSION 4
NATURAL AND ANTHROPOGENE CONTAMINATION, VULNERABILITY AND HAZARDS OF GEOFLUIDS

Chairs: Marco MASETTI | Marijke HUYSMANS

16:00 Keynote presentation by
Daniele PEDRETTI
Geological entropy to measure the spatial disorder of heterogeneous media: from upscaling solute transport modeling in complex aquifers to new fields of applications

16:30 **Jing LI**
Salinity evolution of aquitard porewater associated with transgression and regression in the coastal plain of Eastern China

16:45 **Andrea CITRINI**
Vulnerability assessment of karst aquifers using the COPA+K index-based method: the case of the Valseriana springs (Northern Italy)

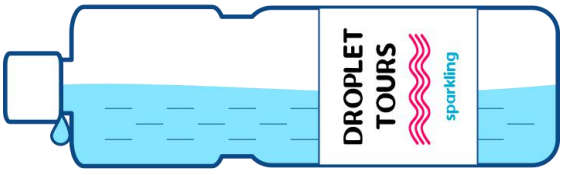
17:00 **Lea AUGUSTIN**
Investigating transport and fate of herbicides in two lysimeters and potential impacts to groundwater

17:15 **Ricardo Leonel MARROQUIN PAIZ**
Estimating surface water – groundwater interactions using a multidisciplinary approach in Río Acomé Basin, Guatemala, Central America

17:30 **Anita ERŐSS**
Geogenic radionuclide contamination in groundwater – a new challenge in drinking water supply

17:45 **Petra BAJÁK**
Natural Uranium Contamination in Groundwater – Understanding the Mobilization and Transport Processes with the Help of Hydrogeology and Geochemical Modeling

18:00 **BUDAPEST SIGHTSEEING**



9 July

SESSION 5
FLUID-ROCK INTERACTIONS AND HYDROGEOCHEMICAL REACTIONS
Chairs: Teodóra SZŐCS | Daniele PEDRETTI

10:00	**Zsolt BENKÓ** Triassic saline fluid flow and epigenetic lead-zinc sulphide mineralization in granite and carbonate basement units along the Transdanubian Shear Zone, Pannonian Basin, Hungary
10:15	**Ekkehard HOLZBECHER** Retardation and Diffusion in Matrix-Fracture Systems
10:30	**Boglárka KIS** Constraints on the hydrogeochemistry and origin of the CO2-rich mineral waters from the Eastern Carpathians – Transylvanian Basin boundary (Romania)
10:45	**Dóra CSERESZNYÉS** Interactions in CO_2-porewater-sandstone system
11:00	**POSTER PRESENTATIONS** Chairs: Marco MASETTI | Ferenc MOLNÁR (2,5 min/presentation)
11:45	**POSTER DISCUSSION IN THE LOBBY**
12:30	**LUNCH BREAK**

SESSION 5
FLUID-ROCK INTERACTIONS AND HYDROGEOCHEMICAL REACTIONS (CTD.)
Chairs: Teodóra SZŐCS | Ferenc MOLNÁR

13:30	Keynote presentation by **Vincent POST** Three-Dimensional Reactive Transport Modelling in Regional Flow Systems: Groundwater-Rock Interaction in the Agricultural Emsland Region, Germany
14:00	**Mariana MENONCIN** Cave sediment analysis of Molnár János Cave – Hungary
14:15	**Márton TÓTH** Hydrogeochemical investigation of medicinal water producing in the Hospital of Parádfürdő
14:30	**Zsuzsa MOLNÁR** Paleo-flow of basinal fluids in the Transdanubian Range (Western Hungary): fluorite veins at Pécsely
14:45	**COFFEE BREAK**

SESSION 5
FLUID-ROCK INTERACTIONS AND HYDROGEOCHEMICAL REACTIONS (CTD.)

Chairs: Ferenc MOLNÁR | Daniele PEDRETTI

15:15	**Aicha SAAD** Baseline for the Assessment of Groundwater Quality for the Economic Development of Ouedd Eddahab Basin (Southern Morocco).
15:30	**Jianwen YANG** Role of Uranium-bearing Brines Location in Controlling the Formation of Unconformity-related Uranium Deposits
15:45	**Jobst WURL** Differencing hydrothermal source rocks through strontium isotopes (87Sr/86Sr).-An example from the Los Cabos Block, BCS, Mexico

16:00 **CLOSING CEREMONY**

POSTERS - 8 JULY
CHAIRS: CATALIN STEFAN I JOHN MOLSON

SESSION 1:
ENERGY FLOW SYSTEMS, RELATED FLUIDS AND THEIR SIMULATIONS

14:00 **P-01**
Ádám TÓTH
Interacting Geofluids Systems in a Shallow Carbonate Basin, Hungary

14:03 **P-02**
Aditya JAIN
Spring Potential Mapping and vulnerability assessment and effect of land-use, climate and human impacts using remote sensing and field measurements in the Uttarakhand Himalayas.

14:06 **P-03**
Hana BEN MAHREZ
Hydrostratigraphical evaluation of deltaic to fluvial series based on spatial and temporal variations of seismic geomorphology, Pannonian Basin, Hungary.

14:09 **P-04**
Luka SERIANZ
Evaluating the relevance of topography driven groundwater flow in a low temperature geothermal system in the Julian Alps, Slovenia

14:12 **P-05**
Szilvia SIMON
Complex flow field due to different fluid driving forces in large sedimentary basins – Pannonian Basin, Hungary

14:15 **P-06**
Juuso IKONEN
Assessing groundwater and seawater mixing using isotopes of H, O, Sr, S and Li in pockmarks with different degrees of groundwater influence at a submarine groundwater discharge site in Hanko, southern Finland

14:18 **P-07**
Yong XIAO
The true face of Karst thermal groundwater system under the mask of cold-hot water mixing

SESSION 2:
MANAGED AQUIFER RECHARGE, ADAPTATION TO CLIMATE CHANGE AND ECOHYDROLOGY

14:21 **P-08**
Gábor NYIRI
Hydraulic modeling of Ranney wells in riverbank filtrated system

14:24 **P-09**
Katalin CSONDOR
Evaluation of a natural uranium contamination of a riverbank filtered drinking water supply system

14:27 **P-10**
Timea TRÁSY-HAVRIL
Effects of recharge reduction on the dynamics of complex groundwater flow systems driven by multiple driving forces

14:30 **P-11**
Piya MOHASIN
Impact evaluation of persistent organic pesticides on the groundwater by an innovative ASTR technology using probabilistic modelling

SESSION 3:
GEOENERGY, THERMAL WATER AND HYDROCARBON SYSTEMS

14:33 **P-12**
Ábel MARKÓ
Approach to understand and avoid injection related problems in geothermal systems

14:36 **P-13**
Brigitta CZAUNER
Abnormal formation pressures: definition, determination and mapping in the Pannonian Basin, Hungary

SESSION 5:
FLUID-ROCK INTERACTIONS AND HYDROGEOCHEMICAL REACTIONS

14:39 **P-14**
Latifa AL YACOUBI
Origin of saline groundwater within fractured crystalline aquifers of the Canadian Shield in Eeyou Istchee James Bay: Case study of Eléonore Mine

14:45 **POSTER DISCUSSION IN THE LOBBY**

Posters - 9 July
Chairs: Marco MASETTI | Ferenc MOLNÁR

SESSION 3:
GEOENERGY, THERMAL WATER AND HYDROCARBON SYSTEMS

11:00 **P-15**
Péter KORONCZ
Is proppant embedment a real phenomenon in the case of Upper Pannonian unconsolidated and friable sands?

11:03 **P-16**
Tamás BUDAY
Investigation of the Geological and Hydrogeological Conditions in North Tiszántúl Influencing the Efficiency of Geothermal Heat Pump Systems

11:06 **P-17**
Nino KAPANADZE
Geothermal potential assessment of West Georgian Lowland

SESSION 4:
NATURAL AND ANTHROPOGENE CONTAMINATION, VULNERABILITY AND HAZARDS OF GEOFLUIDS

11:09 **P-18**
Daniele PEDRETTI
Groundwater rebound and the solute mobility: a "rising" problem

11:12 **P-19**
Giulia CASIRAGHI
Designing a large-scale bioremediation system for in-situ sequential anaerobic-aerobic degradation of organochlorides and hydrocarbons near Venice (Italy)

11:15 **P-20**
Heinz SURBECK
Radium in Geothermal Fluids

11:18 **P-21**
Stefania STEVENAZZI
Impacts of atmospheric nitrogen depositions on ecosystems and groundwater resources

11:21 **P-22**
Lyudmila PETROVA
Maximum concentrations of microelements in mine waters of the South-Eastern Donbass and their influence on the aeration zone of adjacent landscapes

SESSION 5:
FLUID-ROCK INTERACTIONS AND HYDROGEOCHEMICAL REACTIONS

11:24 **P-23**
Judit DÉRI-TAKÁCS
Using hydrogeochemical caracteristics to refine the conceptual model ofgroundwater flow in Wood Buffalo National Park, Canada

11:27 **P-24**
Máté HENCZ
Fluid inclusion study of zoned garnets from the skarn deposit of the Recsk Ore Complex (NE Hungary)

11:30 **P-25**
Piyal HALDER
Mesoscopic observations of fluid-rock interaction at the pre-Deccan Basement rocks up to 1500 m depth in the Koyna Intraplate Seismogenic Zone of India

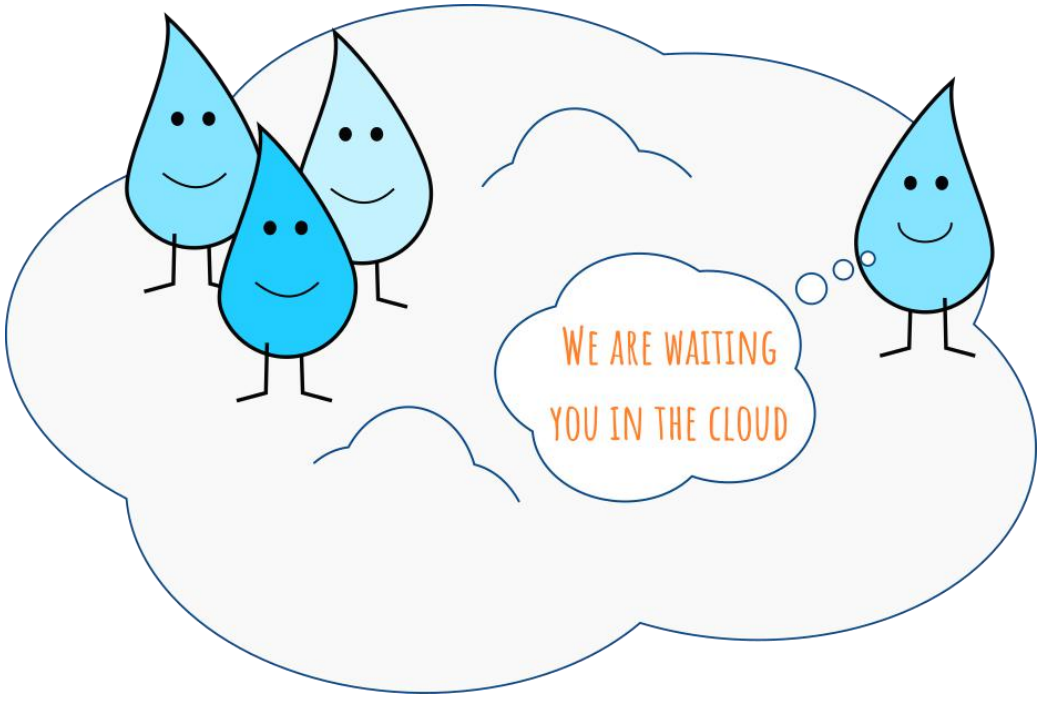
11:33 **P-26**
Andrey OZERSKIY
Three types of reservoirs and fluids in the archean crystalline rock

11:36 **P-27**
Bianca NÉMETH
Detailed Study on Fluid-Rock Interaction in Lower Crustal Garnet Granulite Xenoliths from W-Hungary

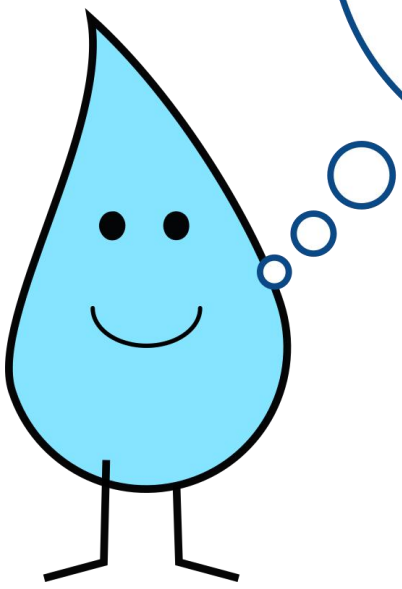
SESSION 3:
GEOENERGY, THERMAL WATER AND HYDROCARBON SYSTEMS

11:39 **P-28**
Marine MARDASHOVA
The prospects to use thermal waters in heat-and-power engineering

11:45 **POSTER DISCUSSION IN THE LOBBY**



ABSTRACTS OF THE KEYNOTE SPEAKERS



in the order of the number of the sessions

Recent progress in hydraulics and hydrochemistry of groundwater flow systems

Xiao-Wei Jiang, Peng-Yu Zhou, Yi-Peng Zhang, Tao-Tao Ji

China University of Geosciences, Beijing 100083, China
jiangxw.cugb@outlook.com

The concept of groundwater flow systems proposed in the 1960s has been widely utilized in various sub-disciplines of hydrogeology. However, understanding of the distribution of flow systems is still mainly based on 2D cross-sections; existing theories of well hydraulics did not account for the regional undulation of potentiometric surface; and the characterization of hydrogeochemical processes is usually based on qualitative analysis of hydrogeochemical components, which led to non-unique interpretations.

In this presentation, we introduce unsteady-state groundwater flow systems and evolution of stagnation points in the 3D basins based on an analytical solution of 3D groundwater flow. The transient groundwater flow field is controlled by a fluctuating water table which is symmetrical to the cross-section from the highest point to the lowest point. When specific storage is small enough, groundwater flow responds instantaneously to the upper boundary condition, but when specific storage is large, there is a lag in hydraulic head to the upper boundary condition, which leads to distortion of flow fields.

Flowing wells are natural outcomes of regional groundwater flow. By considering flowing wells in the discharge area of both confined and unconfined aquifers, the time-decaying discharge rates are compared with Hantush's approach without considering regional undulation of potentiometric surface and water table. The limitation of Hantush's approach is to be examined.

Sandstones are composed of silicates and carbonates, both of which react with dissolved CO_2 and contribute to dissolved Ca, Mg, Sr and HCO_3 in groundwater. Moreover, the cations would be removed by natural processes. To quantify the sources and behaviors of major cations, we collected groundwater in both recharge and discharge areas and use isotopes of Sr, Mg and Li to quantify the major hydrogeochemical processes.

Global water crisis: Managed Aquifer Recharge (MAR) to the Rescue?

Niels Hartog

KWR Water Research Institute, P.O. Box 1072, 3430 BB Nieuwegein, The Netherlands
niels.hartog@kwrwater.nl

Globally, freshwater availability is under pressure, quantitatively by intensifying droughts and demand, and qualitatively by salinization and contamination. With groundwater already providing almost half of all drinking water and irrigation use, the global water crisis is very much also a global groundwater crisis. In addition to its consumptive uses, groundwater is important to maintaining river base flows and groundwater dependent ecosystems. Managed Aquifer Recharge (MAR) techniques may prove critical to sustainably maintain or restore groundwater systems and are a valuable for increasing water availability in water stressed areas by subsurface infiltration and storage, to overcome periods of drought, and to stabilize or even reverse salinization of coastal aquifers. Moreover, MAR could be a key technique in making alternative water resources available, such as reuse of communal effluents for agriculture, industry, and even indirect potable reuse. However, to fulfill the promise of MAR, to become globally significant in securing fresh water availability for the future, MAR techniques will need to be fitted to a wider range of conditions and purposes, in much larger numbers and at much larger scales. With the application of MAR expanding into a wider range of conditions, from deserts to urban and coastal areas, and purposes, from large scale strategic storage of desalinated water and the reuse of waste water, addressing these appropriately will contribute to a greater understanding, operational predictability, reliability and acceptance of MAR applications, and lead to a range of engineered MAR systems that help increase their effectiveness to help secure the availability of water at the desired quality for the future. This talk aims to provide an overview of the development of different MAR techniques for a wide range of purposes and conditions and to point out major directions for developing MAR towards its full potential as a contributor to sustainable fresh water availability.

Numerical modelling of fracture deformation and propagation in development and production of geothermal systems

Inga Berre

University of Bergen, Department of Mathematics, Norway, Bergen
inga.berre@uib.no

Fractures and faults provide crucial fluid pathways in geothermal systems. Deformation and propagation of fractures is a central factor in development and production of geothermal reservoirs as well as in transferring heat from the roots of the system. In this presentation, deformation and propagation of fractures caused by coupled thermo-hydro-mechanical (THM) processes because of fluid convection are studied by use of mathematical models. Through numerical simulations, it is shown how fractures are reactivated, slip, and may also propagate in stimulation of geothermal reservoirs. In the reinjection and production phase, thermal effects caused by forced convection can cause fracture deformation and propagation at the reservoir scale. Finally, we investigate how fracture propagation may also be important for natural convective heat transfer from the roots of a geothermal system. The mechanism is called convective downward migration of fractures and is used to explain the development of high-temperature geothermal systems.

Geological entropy to measure the spatial disorder of heterogeneous media: from upscaling solute transport modeling in complex aquifers to new fields of applications

Daniele Pedretti

Dipartimento di Scienze della Terra "A. Desio", Università degli Studi di Milano, Milan, Italy, daniele.pedretti@unimi.it

Predicting the spatial and temporal scale of solute transport in geological media remains a difficult task. Despite the multiple theories having emerged in the past decades to develop predictive models, in practical applications the way solute transport modeling is performed is often reduced to simple approaches, which often involve oversimplification of the always-heterogeneous geological media. One example is the assumption of equivalent (or effective) homogeneous aquifer properties (e.g. homogeneous hydraulic conductivity, K), which are obtained using improper upscaling methods to parametrize the model. Model oversimplification is also often due to the computational burden of models involving complex parametrization (e.g. stochastic K fields used to parametrize the models). Things get much more complicated if the solute is also reactive and process-based multicomponent reactive transport simulations is involved.

Upscaling models have been introduced to address solute transport in heterogeneous media using computationally efficient approaches. Upscaling is the process by which the scale of measurement of a certain variable is mathematically adapted to the required scale of interest for a model-based analysis. A variety of upscaling methods have been presented for flow and solute transport processes, from surrogate and proxy models to approaches explicitly describing the spatial heterogeneity of the hydraulic conductivity (K) fields. While some methods can properly simulate transport in heterogeneous media, most of them require as input parameters empirical fitting parameters uncorrelated with measurable (physical and biochemical) properties of the flow and transport. This fact limits the use of most upscaling methods for predictive purposes.

In recognition of these limitations, Bianchi and Pedretti (2017,2018) introduced an alternative approach based on the assumption that solute transport behavior is sensitive to the degree of spatial order/disorder in the structure of the K field. This approach is called geological entropy, and several metrics (i.e., the relative entropy index, H_R, and entrogram scale, H_s) were developed based on information entropy concepts (Shannon, 1948). Such methods allow quantifying the degree of spatial disorder of a heterogeneous

media, and because the Shannon entropy can be seen as a measure of unpredictability, these metrics can quantify uncertainty, disorder, and randomness of a system.

This presentation summarizes the development and recent applications of geological entropy. After showcasing the potential of this theory, which reminds to pattern recognition methods and image analysis, we would like to discuss with the audience about the actual benefit of geological entropy beyond solute transport modeling. Our ultimate goal to target potential so-far-not-yet-explored fields where geological entropy could be applied, establishing new potential research collaborations.

Three-Dimensional Reactive Transport Modelling in Regional Flow Systems: Groundwater-Rock Interaction in the Agricultural Emsland Region, Germany

Vincent E.A. Post[1], Georg J. Houben[1], María H. Pesci[2], Jens Gröger-Trampe[3], Jürgen Sültenfuß[4]

[1] *Federal Institute for Geosciences and Natural Resources (BGR), Stilleweg 2, D-30655 Hannover, Germany, Phone: +49-511-643-2393, Email: vincent.post@bgr.de*
[2] *Institute of Hydrology and Water Resources Management, Leibniz University, Hannover, Germany*
[3] *State Authority for Mining, Energy and Geology (LBEG), Hannover, Germany*
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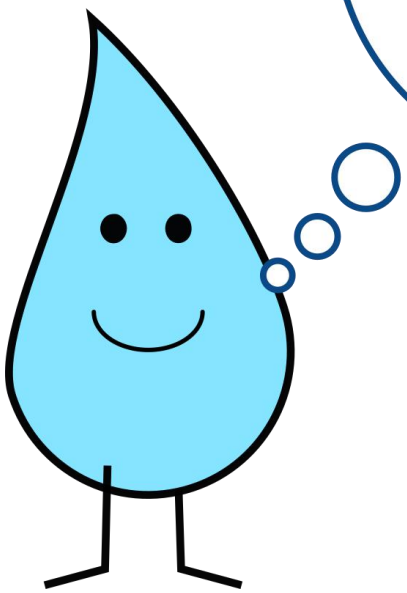
Nitrate pollution is one of the most pervasive groundwater contamination problems in the world. Reactive transport modelling is an important tool to understand the long-term fate of nitrate in regional groundwater systems. Unfortunately, high data requirements and computational demands continue to form an obstacle for the application of reactive transport models at a regional scale. This contribution presents the results of a case study of the sedimentary aquifers in the Emsland region where intensive agriculture is responsible for a high nitrate load. Groundwater nitrate concentrations are attenuated by pyrite oxidation, which leads to elevated sulphate and trace metal concentrations. Using both data and modelling, it will be shown how the nitrate impacted on the groundwater quality. The nitrate input history, an important input into the reactive transport model, was reconstructed from major ion chemistry data, combined with measurements of N_2 excess and tritium-helium groundwater ages. Groundwater flow was modelled at a regional scale using MODFLOW 6 and the regional flow model was used to provide the boundary conditions for a reactive transport model around the abstraction well field. This three-dimensional model integrated the effects of the complex flow field, land use variability, temporally variable nitrate input and geochemical reactions. The model results were validated by comparing them to multi-decadal hydrochemical measurements. The outcomes show that nitrate pollution peaked during the 1970s. Oxidation of pyrite led to a pulse of high SO_4 concentrations that still persists in the aquifers and is the cause for the ongoing increase of SO_4 concentrations in the groundwater abstracted from the water supply wells. The strategy followed in this study is a blueprint that can be adopted in other areas as well and offers the possibility to forecast trends in groundwater quality.

ABSTRACTS



in alphabetical order by corresponding author's first name

Approach to understand and avoid injection related problems in geothermal systems

Ábel Markó[1]; Judit Mádl-Szőnyi[1]; Maren Brehme[2]

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This study proposes a workflow to examine potential reasons for low injectivity which is a major issue related to utilization of thermal waters. To completely understand and avoid the geothermal reinjection problems, potential problem sources acting on different scales should be taken into consideration. Thus, in our workflow, problem sources are considered after categorized into 1) effect of regional hydraulics (potential presence of overpressure and upward flow) 2) inadequate reservoir performance (low extension and low permeability) and 3) local clogging processes (fines migration, mineral precipitation, microbial activity). Hydraulic conditions are characterized by defining the pressure regime and the direction of vertical driving forces. The reservoir properties are given by determining the grain size and the length of the screened sections, as well as the permeability and the transmissivity of the reservoir and the capacity of the injector. Physical, chemical, and biological processes are investigated by specifying the rock properties, clay content; by analysing the type, probability and amount of the scaling; and by evaluating the possibility of biofilm formation.

The workflow was tested on a geothermal site (Mezőberény, SE Hungary, installed in 2012) that had to even be stopped because of the unsuccessful reinjection. The potential reasons were investigated by processing the available dataset (geological, geophysical, geochemical and hydraulic), by modelling (hydrogeochemical, numerical), and by comparing the results to other operating geothermal systems. Based on the results, in the Mezőberény case injectivity decline is a consequence of several separate problems and their interaction: Reservoir properties are insufficient due to low permeability and transmissivity of the reservoir and the limited vertical and horizontal extension of the sandstone bodies. The active vertical length of the screened sections is reduced by inactive segments with lower grain size. Precipitation of carbonates, iron and manganese minerals is expected based on the hydrogeochemical modelling and the solid phase analysis. Microbial products are created due to the particularly high organic content of the produced thermal water that provides organic nutrition. Formation of bioprecipitation and biofouling is also possible. Injection problems due to hydraulic effects are not expected since the pressure regime is hydrostatic and ascending flow was not detected in the close surrounding of Mezőberény. Consequently, reservoir properties determine a low injectivity, which is further decreased to a critical level by the clogging processes.

The proposed workflow can contribute to the detailed reservoir and geothermal system analysis which is essential for a sustainable geothermal use.

Interacting Geofluids Systems in a Shallow Carbonate Basin, Hungary

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The Balaton Highland region (Central Hungary, Europe) is a popular tourist destination with an outstanding ecological value of the Lake Balaton and the surrounding wetlands. Naturally discharging springs have provided high-quality water as a drinking water resource, and CO_2-enriched springwater is consumed by the locals for medical purposes, as well. At the same time, the interest and need for shallow geothermal energy utilisation are increasing. Therefore, the main aim of the study was to disclose the natural hydrogeological processes and the hydraulic and hydrochemical interaction between geofluids (i.e. groundwater, thermal water, CO_2) by field data and numerical simulation of groundwater flow.

Due to the smoothened undulation of the water table, nested groundwater flow systems with low hierarchy evolve; shorter and shallower local flow systems between local highs and lows are superimposed over the longer and deeper flow systems of higher orders. The basin geometry restricts the groundwater flow and causes intensified flow toward the area of Balaton Highland and Lake Balaton.

The subsurface temperature field reflects the advective heat transport caused by topography-driven groundwater flow. The recharging cold water can infiltrate down to -3000 m asl, warm water (>30 °C) can be found only in deeper parts of the basin, except some locally discharging lukewarm-thermal springs.

The hydrochemical composition of groundwater is governed by the carbonate (limestone and dolomite) dissolution. The groundwater is naturally enriched by CO_2 (up to 3000 mg/l) which has mantle origin and transported to the surface by deep regional groundwater flow systems.

The strong interrelationship between the areal distribution and characteristics of geofluids systems determines the groundwater and geothermal intervention possibilities also considering the ecological water needs.

This study is part of a project that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 810980.

Spring Potential Mapping and vulnerability assessment and effect of land-use, climate and human impacts using remote sensing and field measurements in the Uttarakhand Himalayas

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Springs are the de facto groundwater resources of the hills and mountain. Springs are the primary source of water for the rural households. According to NITI Aayog, there are total five million springs and three million springs alone in Indian Himalayan Range. However, due to climate change, anthropogenic effects, lack of awareness and attention, the spring system are today facing the threat of drying up. Due to increased water demand, changing of land use patterns and ecological degradation, spring discharge is reported to be declining. With increasing rainfall intensity and rising temperature, the groundwater recharge tends to decrease, the springs are dying. Climate change and change in biophysical landscape (e.g. land-use and vegetation) are widely implicated in the drying of springs. But there is little systematic knowledge to effectively link climate change, vegetation changes and spring discharge, especially because of large data uncertainties. Rapid socio-economic and demographic changes and infrastructure (dams, roads etc.) have also impacted springs.

Spring potential mapping is identifying areas with high probability concerning the presence of groundwater springs which assists in developing appropriate groundwater exploitation and groundwater resources conservation programs. Over the past two decades, geographical information systems (GIS) and remote sensing techniques (RS) have been the main investigation tools concerning groundwater spring potential mapping. The research thus focuses to bridge this gap by building a spring potential map using machine learning algorithms and predict potential spring sites and their nature depending on various hydrological, topological, geological, and anthropogenic parameters. This will give a huge idea about the actual number of springs and their area of concern.

Using NDVI, which is an indicator of greenness, the ratio can be used in long term for statistical analysis. The green vegetation around springs is quite differentiable in terms of other areas by the presence of ferns. The presence of ferns is used for identifying discharge areas which can be also seen as potential discharge points and hence can be used for vulnerability assessment. The stability of spring discharge is determined by precipitation variability in the spring's recharge area; however, the degree to which spring

discharge is coupled to climate drivers depends on the nature of the recharge, flow-path length, and groundwater residence time. Thus, the objective is to assess the vulnerability of certain selected springs based on their nature and community interviews by performing a long-term statistical analysis of NDVI and estimating the vulnerability by certain parameters like mean, std dev, CV, etc between the spring area and non-spring area. An additional parameter of climate change as rainfall is added to assess the response of springs. Further, this is supplemented by social surveys and community involvement and finding easy solutions to revive the springs and make it more sustainable.

In a nutshell, this research aims to work on lowering of the big data gaps in the intricated area of the Himalayas in state of Uttarakhand, India. It addresses the climate change and land-use change patterns and assess the vulnerability to see the potential future trends and analyse possible scenarios and suggest revival techniques for the sustainable management of springs.

Suitability mapping of MAR schemes in Hungary

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We have reviewed best practices and benchmark analyses on Managed Aquifer Recharge (MAR) solutions in the European Union and developed a Transnational Decision Support Toolbox for designating potential MAR locations in Central Europe. This work has been performed within the DEEPWATER-CE project and is funded by the European Regional Development Fund via the Interreg Central Europe programme. A suitability mapping was carried out based on this Toolbox. This includes national screening for perspective pilot areas and selection of a specific pilot area to explore the possibilities of an underground dam installation. The aim of this mapping was to delineate a specific site where a preliminary feasibility assessment will take place.

General mapping of geological and hydrogeological conditions covered entire Hungary. Maps were prepared for 6 selected MAR types according to different limiting parameters as constraints. The aim of this screening was to outline potentially suitable areas for further studies. The potentially suitable regions were selected based on existing maps and databases. In the case of Hungary, the underground dam MAR scheme was selected for further investigation (by specific mapping). The Maros alluvial fan was found as a perspective area for this scheme and it was selected as pilot area.

The specific mapping process included the suitability characterisation of 8 selection criteria. Based on available geological and hydrogeological maps, databases, and previous regional studies, 3 suitability categories were distinguished. As a result, approximately one third of the area was found to be highly suitable for the underground dam MAR scheme. The storage and barrier subsurface structures, as well as the depth of the semipermeable/impermeable layer were identified as the most crucial factors for suitability. 5 potential sites were determined, out of which at one a detailed preliminary feasibility study will be carried out.

Baseline for the Assessment of Groundwater Quality for the Economic Development of Ouedd Eddahab Basin (Southern Morocco)

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The East side of Oued Eddahab basin will experience significant economic and demographic development soon following a strategy of the Moroccan government which is part of the new model of development of the Southern provinces. A study was conducted to assess (i) the groundwater quality of the Lower Cretaceous fossil aquifer and (ii) the water suitability for irrigation and drinking water. Water quality for irrigation was assessed with Wilcox and Riverside diagrams.
Suitability of groundwater for drinking purpose was based on TDS and Total hardness as $CaCO_3$.
The results indicated 4 classes of water suitability for irrigation (from good to unsuitable). High and very Hight values of EC will have an impact on crop productivity and reduce the yield potential. Classification of suitability for drinking water showed 2 classes from fair to an acceptable based on TDS and one class very hard based on Total hardness.

With this study we aimed to establish a baseline for guiding the different uses of groundwater resources.

The forgotten facts of the visibility of groundwater

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The classical view that groundwater is invisible has resulted from tracing its presence below the land surface with most research made on subsurface elements proper of indirect methods such as geophysics. However, groundwater continuously travels starting at the land surface in a recharge zone, afterwards it visibly re-emerges at the surface under discharge conditions. Therefore, different groundwater interactions occurring in the geological context are manifested at land surface as part of the water-cycle determining the characteristics of the Earth's surface and biosphere. Using the theory of Tóth on the groundwater flow systems the surface hydrogeological features in Mexico were defined. Surface indicators of manifestations of groundwater flow systems were analysed to understand the systemic uniqueness of water in the geological setting, relief, soil, rivers, water bodies, and vegetation. A systemic hydrogeological analysis was made of regional surface indicators published in official freely accessible cartographic information at scales of 1:250 000 and 1:1 000 000 resulting in six maps of Mexico: "Permanent water on the surface", "Groundwater depth", "Hydrogeological association of soils", "Hydrogeological association of vegetation and land use", "Hydrogeological association of topoforms", and "Superficial evidence of the presence of groundwater flow systems". Results show 30% of the Mexican territory is covered by discharge zones of groundwater flow systems (local, intermediate, regional). Recharge processes occur naturally in some 57% of the country. This research is the first holistic analysis of groundwater carried out at a national-regional scale using official information available to the public. Results may be used as a base for more detailed groundwater studies, its role in the dynamic equilibrium of ecosystems and environment, and to satisfy human needs under an innovative visible framework.

Vulnerability assessment of karst aquifers using the COPA+K index-based method: the case of the Valseriana springs (Northern Italy)

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The Valseriana is a Pre-Alps valley located in the province of Bergamo (Northern Italy). It is characterized by high water availability due to the combination of its karst environment and a high average precipitation rate (2000 mm/year). Therefore, its main springs (Nossana and Ponte del Costone) assume a strategic importance for the water domestic service of the city of Bergamo and other municipalities in the area. Proper management oriented to the preservation of these water systems is crucial. Intrinsic vulnerability maps are currently one of the most valuable tools for assessing the pollution sensitivity of an area. Index-based methods allow its assessment even in cases where large amounts of data are not available and without requiring intense computational effort.

The study aimed to evaluate and improve index-based approaches to assess intrinsic vulnerability including the specific characteristics of the Pre-Alps region. First, the classical methods for karst environments were applied (COP and EPIK) using GIS software. These evaluation techniques did not allow to underline the different behavior of the two springs (dominant drainage system Nossana, dispersive system Ponte del Costone). Therefore, the COP method was extended in the COPA+K approach by adding two further factors. In detail, the influence of major discontinuities on the water system according to their distance from the spring (A factor) and the development of the karst network (K factor) were considered. The statistical analysis of the results revealed the advantages of using this new method in this area compared with COP and EPIK. COPA+K allowed a greater detail in the identification of the most vulnerable areas (from 35.6% to 23.6% considering the whole area) and the percentage difference between the most vulnerable areas of Nossana and Ponte del Costone increased from 5.2% to 17.5%.

Effect of basement leakage in contrast with the common no-flow base conditions in 2D Tóthian flow

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The term basement has different meanings depending upon the discipline it is used in and the purpose of using the term whether it is purely descriptive or used in analytical and numerical models. In geology the term basement often refers to the first encounter of igneous, metamorphic, or plutonic rock that could occur at the surface or at great depth. Strictly speaking in hydrogeological terms, a basement could be an aquifuge, which contains zero porosity and no water as well as zero permeability or an aquitard that contains storage but effectively zero permeability. As groundwater scientists we understand that these conditions are rarely if ever meet. Notwithstanding this, we in the hydrogeological community often make a decision on thekkehe so-called hydraulic basement knowing that it most likely is not strictly correct. Our chosen basement occurs at the bottom of the zone that we are interested in modelling and we assign the boundary condition as a zero flux or no flow boundary. For example, this basement could be an aquitard at the bottom of an unconfined aquifer or a crystalline rock at the bottom of a stacked sequence of aquifers. However, as discussed by Tóth (Tóth 2009, 2016) the emerging new view of hydrogeological science is that no geological material is impervious and leakage between different units is of paramount importance in the development of conceptual and numerical models. In this presentation we compare the classical benchmark simulations of 2D flow by József Tóth (Tóth 1962, 1963) by adding basement head or flux conditions to induce downward flow in under-pressuried conditions and conversely upward flow in over-pressurised conditions. Single and multi-hydraulic conductivity layers as well groundwater ages are examined.

Three types of reservoirs and fluids in the archean crystalline rock

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Hydrogeological conditions of archean rock massif were investigated for building of the geological repository for radioactive wastes isolation in the southern part of the Yenisseyskiy ridge (Siberian Craton). Exploration methods included well boring up to depth of 700 m, geophysical logging, hydrogeological pumping tests, water, and rock sampling. 228 pumping tests were carried out with systematically scaled intervals of 50 meters isolated by packers. Core samples were tested in porosity and permeability.

Rock massif is presented by lower archean gneisses pierced by dykes of dolerite with low reservoir properties due to an intense metamorphism. All crystalline rocks are formally considered to be impermeable according to the Russian standard. However up to depth of 700 m rock massif contains a small quantity of liquid fluids. These fluids are found in three types of reservoirs.

1) Nanoporous type is observed in monolithic non-fissured rocks by laboratory tests only. Their hydraulic conductivity is equal to n·10-5 – n·10-6 m·day-1. The permeability is created by intergranular interstices. The fluid in the nano porous medium is still.

2) Nanofissured type has hydraulic conductivity n·10-4 m·day-1. This type is predominated in the rock massif, 93% of all field tests belong to it. This type of reservoir determines the water pattern of the whole rock massif. The movement of the fluid is determined here by pressure, as well as by capillary and viscous forces.

3) Microfissured and vein type formed by weathering fissures and rare tectonic cracks. Hydraulic conductivity is about n·10-3 m·day-1. This fluid is usual free groundwater that flows according to Darcy's law.

Forecast methods should be different for each reservoir and fluid.

Geogenic radionuclide contamination in groundwater – a new challenge in drinking water supply

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The geological environment, in addition to providing beneficial mineral content to groundwater, may also give rise to undesirable or toxic properties through an excess of various elements. Groundwater may contain different natural alpha (U-238, U-234, Th-232, Ra-226 and Po-210) and beta emitters (K-40, Ra-228 and Pb-210) in various concentrations. Radiation exposure through drinking of groundwater-derived waters can result from alpha-radiation-emitting uranium, radium, and their progeny, including radon, a significant impact on human health. Usually gross alpha and gross beta activity analysis is used for the characterization of radioactivity in drinking waters as a screening method, because of the relatively low costs and simplicity of the method. As a result, this method was implemented in several cases in national and international regulations related to the new drinking water quality directive concerning radioactivity. However, many uncertainties were identified related to this method. To explain the origin of the measured gross values, and provide solution possibilities for the waterworks, groundwater flow system understanding is a key issue. In addition, here we show a simple nuclide specific analysis method for uranium and radium using selectively adsorbing discs. Our case studies highlight, that the combination of flow system analysis and nuclide specific measurements provides only sufficient insight to the interconnection between geology, flow systems and the occurrence of natural radionuclides in groundwater.

Topohaline and Topothermohaline Convection in Regional Groundwater Flow Systems in Synthetic and Real Hydrogeological Environment

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Regional groundwater flow (GWF) is driven mainly by the water table topography at least in the upper part of the continental basins. However, in deeper zones or in confined aquifers other driving forces can appear which influence or even dominate the flow system, such as the negative buoyancy force due to dissolved solid content and the positive buoyancy force due to thermal expansion of the pore water.

First, two-dimensional numerical simulations were carried out to systematically quantify the interaction of the topography and the salinity in synthetic basins. Based on the numerical calculations, increasing density due to salinity and decreasing water table amplitude facilitate the GWF system transition from topography-dominated freshwater system to a diffusion-dominated layered regime. The decrease of permeability and the increase of dispersivity result in similar processes, both extinguish the relative role of advection by enhancing the diffusion or dispersion, respectively. The two phenomena strengthen the coupling between the fresh and saltwater zones.

Second, the combined effect of topography-, salinity- and temperature-driven GWF was analyzed in simple, synthetic basin-scale numerical models. The increase of the permeability and the water level gradient intensify the GWF, cool the basin and reduce the salt content. On the contrary, the enhanced permeability anisotropy and salinity favour the formation of a dense saline layer in the deepest zone of the basin. This sluggish layer retards the heat from below, which heats up the layer, induces thermal buoyancy and results in thermohaline convection within the salt layer. In addition, a near-surface freshwater zone evolves dominated by topography-driven GWF. Beyond the synthetic simulation set, case studies represent the phenomenon of topohaline and topothermohaline convection in simplified hydrogeological environments.

This research is supported by the ENeRAG project which has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 810980.

Detailed Study on Fluid-Rock Interaction in Lower Crustal Garnet Granulite Xenoliths from W-Hungary

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Two silicate melt inclusion (SMI)-bearing mafic garnet granulite xenoliths were studied from Plio-Pleistocene alkali basalts of the Bakony–Balaton Highland Volcanic Field (Hungary). Both xenoliths can be considered as migmatite, consisting of a paleosome and a neosome part.

Geothermobarometric calculations show that the equilibrium temperature of the melanosome is 920 °C in the Mi26 xenolith and 840 °C in the Sab38 xenolith, while their equilibrium pressure is ~1.2 GPa.

The plagioclase (Pl) and clinopyroxene (Cpx) of the leucosome, as well as the ilmenite (Ilm) occurring in symplectites at the border of leucosome and melanosome, contain primary SMIs with peraluminous dacitic to rhyolitic composition. The SMI-bearing clinopyroxenes of the leucosome crystallized at 930 to 940 °C and 3.7 (Mi26) to 5.6 (Sab38) kbar, while plagioclases crystallized at a slightly lower temperature (Mi26 ~860 °C, Sab38 ~870 °C). The calculated water content of the melt based on plagioclase/melt pairs is ~3 wt.% in both xenoliths.

The major and trace element composition of SMIs suggests, that they derived from the melting of a metasediment — (MORB-like) metabasalt mélange and leaving behind a Pl + Cpx + orthopyroxene + Ilm residue.

The SMIs trapped in plagioclase and ilmenite represent melt drops remaining after various degrees of melt – garnet granulite interaction. The formation of Cpx-Ilm±Pl symplectites required pre-existing titanites, which reacted with the felsic silicate melt to generate Cpx, Ilm, Pl, and a silicate melt with a modified composition compared to the original melt.

The percolating melt represented by SMIs has no connection with the alkaline basalt, which brought xenoliths to the surface, on the other hand, their composition is similar to the pre-Miocene calc-alkaline magmas found in the northern part of the Pannonian Basin.

The dissemination of the results is supported by the ENeRAG funded by the EU's H2020 research and innovation program under grant agreement No 810980.

Constraints on the hydrogeochemistry and origin of the CO2-rich mineral waters from the Eastern Carpathians – Transylvanian Basin boundary (Romania)

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The Eastern Carpathians, along the Neogene to Quaternary volcanic chain, host important natural resources of mineral waters. Most of these are in the form of CO_2-rich natural springs of different types, associated with CO_2 gas emissions.

In order to understand the origin of these waters, the natural processes responsible for the observed physical-chemical features and to check the exposure and vulnerability of the hydrogeological system to potential contamination and environmental changes, more than 100 mineral water springs and wells were investigated. The investigations performed, offered an insight on the processes affecting the waters after their infiltration that led to a wide range of chemical and isotopic compositions.

The diversity in the geological structure of the area, alteration processes and interaction with CO_2, all explain the variety of the hydrogeochemical facies of the investigated waters. Three major hydrogeochemical types that are the result of the geological variety of the study area and water-rock interaction were identified: Ca-Na-Mg-HCO_3, Ca-Na-Mg/Na-Ca ± Mg-HCO_3-Cl ± SO_4, and Na-Cl waters. Further changes in the geochemical features are attributable to mixing between different water types during their ascent, enhanced by the tectonic setting of the area.

Considering the isotopic composition ($\delta^{18}O$, δD) of the waters, most of them proved to be of meteoric origin. Extreme isotopic shifts towards enriched $\delta^{18}O$ and δD values of +8.59 and −12.2‰ (V-SMOW) respectively were observed in the case of 11 springs. These shifts were attributed to the interaction of water with clay minerals and diagenesis. As most of these waters are of meteoric origin, their discharge may be influenced by meteorological factors. Moreover, the mixing of aquifers with very shallow waters most likely facilitates their exposure to external contamination.

This work was supported by a grant of the Romanian Ministry of Education and Research, CNCS - UEFISCDI, project number PN-III-P1-1.1-TE-2019-1908, within PNCDI III and the project GTC 32144 supported by Babes-Bolyai University, Romania.

Abnormal formation pressures: definition, determination and mapping in the Pannonian Basin, Hungary

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Since groundwater flow is the dominant mechanism for transporting mass and energy in sedimentary basins, knowledge of the dynamics of flow is a fundamental prerequisite to understand geologic processes, formation and exploration of geological resources. Sedimentary basins are subjected to several forces known to cause large-scale fluid migration such as relief of the watertable, tectonic compression, compaction, buoyancy, and their com
bined effects. The watertable relief results in basin-scale gravitational flow systems with formation pressures being close to normal or hydrostatic. However, the rest of the driving forces usually generate transient flows characterized by abnormal pressures. This study presents a methodology for the determination of abnormal pressures as the lower boundary of gravitational flow systems. Method was developed for hydraulic head and pressure data as well. Moreover, in pressure vs. elevation profiles boundaries of over-, normally- and underpressured regimes were defined. As a case study, boundary of the overpressured regime and the superimposed gravitational flow systems was investigated in the Great Hungarian Plain (Pannonian Basin, Hungary). Overpressure in the Pannonian Basin originated from compaction and tectonic compression, and maintained by regionally effective aquitard layers, can exceed 200% compared to the normal value. As a result, it represents a significant driving force for geofluids and a severe challenge in drilling activities. In addition, the overpressured zone is hydraulically closed system with non-renewable groundwater resources, thus knowledge of the occurrence and controlling factors of overpressure can help in the sustainable production of georesources (e.g., groundwater, geothermal energy, petroleum) from this zone. The research is supported by the ENeRAG project received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 810980.

Modelling of managed aquifer recharge schemes in near-real time using the INOWAS web-based simulation platform: experiences from a WaterJPI research project

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The negative impact of human activities and climate change on ecosystems requires the diversification and further development of adaptation strategies. The concept of managed aquifer recharge (MAR) includes technical and nature-based interventions aimed to store different types of water in the aquifers and subsequently enable the use of recovered water for multiple purposes. The MAR types and objectives are manifold and so are the risks that can arise during the planning, implementation, and operation of a MAR facility. The solution proposed by the WaterJPI project "SMART-Control" (www.smart-control.inowas.com) combines the identification and characterization of MAR-associated risks with the development of an innovative web-based, real-time monitoring and control system. The approach consists of an in-situ real-time monitoring scheme and a web-based platform for control, modelling and prediction. To demonstrate its feasibility, the concept is deployed at six MAR sites in Germany, France, Cyprus and Brazil with various characteristics (from pilot-scale schemes to full-scale municipal facilities). The concept consists in the installation of specific multi-probe monitoring sensors equipped with data logging and transmission, and the development of software infrastructure required for data acquisition and management. Data gathered in near-real time from the monitoring network is then collected, pre-processed, and visualized using a newly developed tool implemented on the free, web-based groundwater modelling platform INOWAS at TU Dresden. The platform includes simulation tools of various degree of complexity, from simply empirical and analytical tool to numerical (MODFLOW) tools and optimization algorithms. In the SMART-Control project, a new set of tools are developed to assist the operational management of MAR sites and enable the automatic data processing. The presentation introduces the preliminary outcomes obtained from the project and the lessons learned.

Groundwater rebound and the solute mobility: a rising issue for aquifer risk assessment

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The steady increase of groundwater head levels because of the closure of large well fields is a widespread problem for many urban areas all over the world. While the socio-economic effects of groundwater head level rising on subsurface infrastructures have been well documented, the environmental implications of groundwater head level rising remain less explored.

Little is known about the potential effects of groundwater head level rising on the formation of solute plumes from contaminant sources that lie in the vadose zone and that groundwater head level rising may mobilize with time.

In this presentation, we evaluate the mobilization of buried contaminant sources in a stratified highly heterogeneous aquifer near Naples, Italy. A dismissed chemical factory caused a multicomponent solute plume contamination which was hydraulically confined by a pump-and-treat (P&T) system. Since 2011, concentrations of contaminants such as 1,1-dichloroethene (1,1-DCE) were found to exceed regulatory maximum concentration levels in monitoring boreholes outside the P&T.

We hypothesized that such occurrence was linked to the groundwater head level rising, as the P&T was correctly working before 2011. Using a combination of stratigraphic geological analysis, time series of monitoring head levels and concentration records and a numerical flow and transport analysis, the hypothesis was demonstrated as plausible.

The model considers a contaminant source located above the position of the water table in 2011. The source was progressively saturated by the rising groundwater. This resulted in enhanced advective transport components at the source, which generated a simulated solute plume that scales in space and time according to the field measurements.

We demonstrate the ability of the proposed methodology to quantify the potential implication of groundwater head level rising in similar settings, a phenomenon which is expected to become increasingly important in the future.

Groundwater flow systems in Petorca River Basin, Chile: Their contribution to improve water management and protection

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The Petorca River Basin in Central Chile (~32°15'S/70°56'W) is known as the national symbol of the water crisis. Similarly, as in northern and central Chile, Petorca has been affected by an uninterrupted sequence of intense droughts since 2010, called the Chilean Mega-Drought. The main channel of the Petorca River and many of its tributaries are entirely dried also shallow groundwater has been affected, causing harmful environmental and social consequences. Additionally, privatization and inequitable water distribution have aggravated these conditions. In this scenario, it is urgent to understand the groundwater behaviour and its flows in 3D through a systemic approach that faces this socio-environmental issue. Thus, this study seeks to identify and characterize the groundwater flow systems in the middle and upper part of the Petorca Basin, through qualitative and quantitative methodologies. Interviews and participatory mapping were used to produce the hydrosocial characterization of the basin. Also, a Tóth groundwater flow systems model were performed based on the analysis of geological, geomorphological, soil and vegetation information plus field measurements of temperature, pH, Eh, dissolved oxygen and electrical conductivity, as well as chemical (metals, metalloids, anions) and isotopic (2H and 18O) analysis of water samples collected in wells and springs. The challenge is to define groundwater recharge, discharge, and circulation conditions. The results of this study have allowed proposing a series of management measures that might assist to conserve water sources and ensure their good quality and promote justice over water in this territory.

Interactions in CO_2-porewater-sandstone system

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Our study area is located in the Little Hungarian Plain (W-Hungary) which is one of the largest commercial CO_2 producing fields in Central Europe. In this region, we have the opportunity to study CO_2-free (not affected by natural CO_2-flooding) and CO_2-flooded sandstones in the same geological formation. Sandstone is one of the most potential reservoirs to inject and store CO_2 (CCUS, Carbon-dioxide Capture, Utilization and Storage) on geological time scale worldwide. To better understand the processes, taking place during and after CO_2 injection, petrographic observations, scanning electron microscopy and mineral chemistry analyses, X-ray diffraction and infrared spectroscopy were used on seven CO_2-free and six CO_2-flooded sandstone samples (from drilling core) to determine texture features, mineral compositions, and the presence of OH^- containing minerals. A descriptive geochemical model is also coupled to the laboratory analyses. We carried out kinetic batch modelling with PHREEQC geochemical software. In addition, sensitivity analysis was also performed for the chemical composition of porewater.

The petrographic observations and XRD results revealed that the albite-rich plagioclase content is higher (~ 11 w/w%) in the CO_2-free samples compared to the CO_2-flooded ones (<1 w/w%). This can be explained by the precipitation of dawsonite ($NaAlCO_3(OH)_2$) driven by CO_2 flooding. Albitic-plagioclase can dissolve as result of CO_2-flooding and serve as Na^+ and/or Al^{3+} source for dawsonite formation being an indicator mineral of large amount of CO_2 inflow in the CO_2-water-rock system.

The study of this area provides opportunity to improve our geochemical models on sandstone that interacts with large amount of CO_2.

Dóra Cseresznyés' work is supported by the Cooperative Doctoral Program (KDP-2020/971244) granted by The Ministry for Innovation and Technology (ITM) from the source of the National Research, Development and Innovation Fund.

Retardation and Diffusion in Matrix-Fracture Systems

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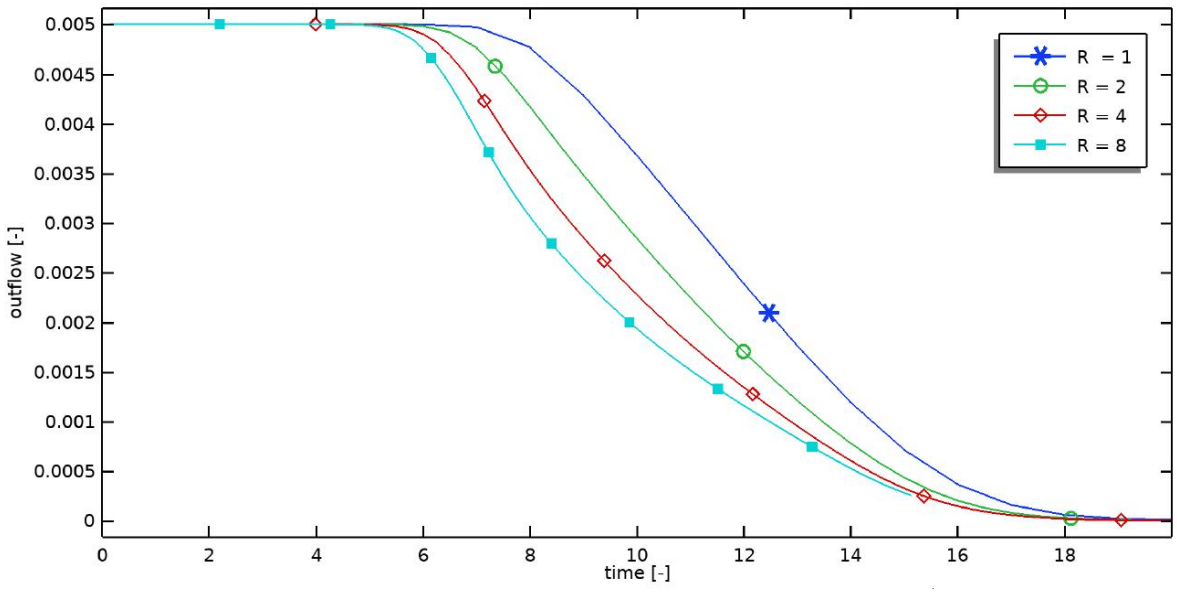
Matrix-fracture systems are of special interest for geologists, as they appear frequently in the natural environment. In contrast to fracture networks as one extreme and continuous porous media as the other extreme they are characterized by the fact that flow and transport characteristics are determined by both the fracture and the matrix.

Flow in such systems has been examined in many studies, but transport has attracted less scientific attention. This study approaches the problem using finite element modelling. In order to understand the processes in the micro-scale open fractures with different orientation and aperture are studied that abogláre located within a porous matrix.

Fluid-solid interaction in the matrix is represented by a retardation factor. The numerical experiments reveal that the matrix-fracture constellation leads to additional diffusion and reduced retardation. The results of parametric sweeps with the relevant parameters are visualized on breakthrough curves. The study shows how effective transport properties in the systems are determined by geometric characteristics of the fractures within the porous matrix.



Effective breakthrough curves in dependence on retardation R in the matrix; time is normalized to eliminate pure retardation effect

Hydraulic stimulation treatments in the geothermal injection well in Mezőberény, Hungary

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Reasons for injectivity decline were investigated at a geothermal site located in Mezobereny, SE Hungary. The injection well is about 2 km deep and completed with a gravel pack between 1.6 km and final depth in a sequence of sandstones, siltstones, and marlstones with several screens in between which allow access to the formation. Due to low injectivities, potential production rates are reduced, and the site faces negative commercial implications.

In addition to historical operational data, fluid and rock samples were investigated in laboratory. Analyses and experiments focus on physical, chemical, and biological processes and their interactions. Results show different processes being responsible for injection-triggered occlusion of flow pathways. Fines migration may be caused by washouts in loosely cemented rocks, from where fine sand or clay particles are transported and injected into lower aquifer layers. Precipitation of minerals may be caused by cooling or exposure of oxygen. Biological activity is observed at production and injection site.

In order to fully understand the processes taking place in the injection well, borehole tests and measurements were done in spring 2021. Preliminary results of an injection test show a significant damaged zone around the well with low permeability in the order of up to a few meters and a far field with a higher permeability. Logging data characterize the gravel pack set up and temperature measurements after cold water injection indicate different quality of screens in the gravel pack section.

After delivering this abstract, a specially tailored stimulation concept will be applied in the injection well to overcome the above-mentioned damage zone. Results will be presented in July.

Activities are taking place in the frame of the DESTRESS project. The DESTRESS project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 691728.

Energy efficiency of thermo-active micro-piles

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Energy piles (EPs), representing piled foundations serving the dual purpose of providing structural support to the overlying building and exchanging heat with the ground for building heating/cooling purposes, have been extensively studied in recent years, both from the thermo-mechanical response and energy performance points of view. However, most research refers to typical rotary bored, CFA or precast driven, medium to large diameter foundation piles. Truly little attention has been devoted to so-called energy micropiles (EMPs), representing an innovative and timely opportunity to provide, at the same time, energy and structural retrofitting to existing buildings. Existing studies show that EMPs overall may thermally perform differently to EPs, but they are comparable in terms of specific heat flux.

In this work, a 3D Finite Element numerical model is employed to perform a comprehensive parametric study, considering both design-dependent and site-dependent factors that are peculiar to EMPs, to assess the most important parameters to maximize their energy performance. The parameter space is efficiently explored resorting to a statistically based approach, so-called Taguchi method. Results show that thermal design of EMPs should not be based on the same criteria as those used for medium-large diameter EPs, since different parameters are dominant in enhancing their energy performance. In particular, the pipes diameter should be maximized in EMPs for its strong influence in results, while being very easy to engineer.

Hydraulic modeling of Ranney wells in riverbank filtrated system

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Riverbank Filtration (RBF) is widely used in drinking water production all over the world. In Hungary, about the 30% of drinking water comes from these types of drinking water sources. These types of water sources have a typical water production facility called Ranney-wells. Ranney wells has two main parts: the cassion in the center, and the horizontal arms. In our work we used different types of modeling methods in order to invertigate the hydraulic conditions of these type of wells. During our work comparative analyses were performed, to get knowledge about the applicability of MODFLOW Revised Multi-Node Well (MNW2).

Riverbank filtration systems also play a big role in the water supply of Budapest. The water supply of the Hungarian capital is largely provided by RBF systems located on the riverbank of the Danube. In our work we deal with the water reserve located on the Szentendre island, where the water is extracted by Ranney wells. In our work we deal with the hydraulic conditions of the riverbank filtrated system of the Szentendre island. During the modeling process MODFLOW MNW2 module was used to get a picture about the hydraulic conditions. The main objective of our work is to investigate the modeling applicability of the MNW2 code for Ranney-wells, and with the help of MNW2 define more precisely the well-geometry during the modeling of riverbank filtration systems.

Designing a large-scale bioremediation system for *in-situ* sequential anaerobic-aerobic degradation of organochlorides and hydrocarbons near Venice (Italy)

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Pollution by toxic organic chemicals is a worldwide issue that threatens groundwater resources all over the world. Bioremediation has proved to be the method of choice when dealing with these contaminants. Especially when a large-scale intervention is required, the design of an efficient in-situ bioremediation system requires a multiscale approach (e.g. El Mamouni et al., 2002; Major et al., 2002) combining laboratory and field-scale activities.

This study summarizes the activities carried out for the construction of a large-scale bioremediation system at a polluted site near the Venice lagoon (Italy). The pollution in the local aquifer is caused by leakage from an old industrial landfill that borders with the lagoon and has produced significant petroleum hydrocarbons (PHCs) and chlorinated aliphatic hydrocarbons (CAHs) contamination. The area is located below sea level and is subject to land reclamation through a drainage groundwater channel which imposes a local groundwater flow direction opposed to the regional flow from the mainland to the lagoon, causing the contaminants to migrate from the landfill to the mainland.

Since different organic contaminants are more efficiently degraded under different redox conditions (e.g. Lee et al., 1988; Aulenta et al., 2006), sequential stimulation of in situ anaerobic/aerobic biodegradation through two biobarriers located in sequence downgradient of the landfill was considered.

To evaluate the feasibility of such a system, first, the in situ presence of bacterial communities able to degrade the target contaminants was confirmed by polymerase chain reaction (PCR) analysis. Microcosm experiments pointed out the necessity to add bio-stimulating compounds for an efficient degradation under both aerobic and anaerobic conditions. In the second step, the efficiency of stimulated in situ biodegradation was confirmed in a pilot-scale study. Two 40 m long biobarriers (for anaerobic and aerobic degradation, respectively) intercepting part of the contamination plume were installled perpendicular to the groundwater flow direction. Results showed a significant drop in contaminant concentrations, with removal efficiencies of up to 95% and 99% for total CAHs and PHCs, respectively, proving the feasibility of the system and leading to the subsequent realization of two microbial barriers more than 400 m long for the interception of the entire contaminant plume.

Hydrostratigraphical evaluation of deltaic to fluvial series based on spatial and temporal variations of seismic geomorphology, Pannonian Basin, Hungary

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This research focuses on the stratigraphic architecture and disposition of deltaic and fluvial sands within the Late Neogene Pannonian basin-fill succession in Eastern Hungary.

The lithologies are identified from seismic interpretation and well logs evaluation, to develop a quantitative hydrostratigraphic classification of the sequence. Hydrostratigraphic divisions are based on the hydraulic conductivity of the rock bodies, depending primarily on the extent and connectivity (lateral and vertical) of sand bodies embedded in various muddy lithologies. Thus, we are going to build up a simplified 3D lithological model for the uppermost 1500 m of the basin fill succession, that will be transformed into hydrostratigraphic units and used in numerical flow models as hydraulic conductivity values. The change of depositional environments and the direction of the sediment flow during the Neogene-Quaternary is reflected in the spatial-temporal disposition of sand deposits and therefore appears as different hydrostratigraphic units in the model.

The study region's extent is approximately 50 x 40 km2 containing 5 merged three-dimensional seismic cubes covering the area. First, 7 master horizons, then several proportional slices were delineated in different attribute maps (e.g. amplitude, Root Mean Square amplitude, similarity variance, dominant frequency). The purpose of attribute maps is to investigate the seismic geomorphological features and their associated depositional environments. Basic wireline logs (gamma, spontaneous potential) from 119 wells were interpreted simply in terms of sand, mud, and heterolithic muddy-sand, and finally were tied to the seismic cube. The combination of these two methods: seismic geomorphology and lithology extraction from well logs allows the identification of sandy deltaic lobes, sandy fluvial channel belts, and the muddy flood plains. Based on the lateral extension and density of sand lithology, percentages of sand vs clay (net-to-gross; N/G) as well as sand connectivity percentages were determined.

Above the deltaic succession, a fluvial depositional environment takes place and can be divided into units. Starting by a meandering system, with 500-3600 m wide channel belts and therefore a high N/G. Then, a transition into an anastomosing river system is observed, it is characterized by channels about 100-200 m wide, with lower N/G ratios and less connectedness. In the upper part of the fluvial succession, the large meandering channel belts returned to the area. These changes in river style and paleo-hydrography affect the sand and clay ratio and their connectivity; therefore, the previous hydrostratigraphic units' decomposition must be reconsidered.

The dissemination of the results is supported by the ENeRAG project funded by the European Union's Horizon 2020 research and innovation program under grant agreement No 810980.

Radium in Geothermal Fluids

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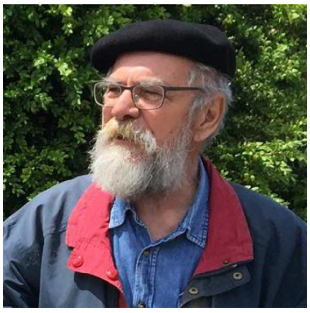

Thermal waters from springs and wells in Switzerland are known to have increased ^{226}Ra activity concentrations, up to some 100 mBq/l. Only few ^{228}Ra measurements have been done. A deep geothermal project in Western Switzerland has created new interest in not only ^{226}Ra, but also ^{228}Ra measurements. Uranium, ^{226}Ra and ^{228}Ra have to be measured in the water released to a publicly accessible water body. The limits given are for weekly averages. Results thus have to be available within about a week to make a decision if the release point has to be changed. There is no time to wait for months until a considerable amount of ^{228}Th has been built up from ^{228}Ra.This has been the motivation for the work presented : to have a closer look at what happens with the radium daughter products after the mothers being adsorbed on a MnO_2 thin film. Is there for instance an optimal time window to measure ^{224}Ra as a proxy for ^{228}Ra? The films are thin enough to allow for alpha spectrometry at high energy resolution. Three of the four radium isotopes decay by alpha particle emission to a radon isotope. These radon isotopes have very different half-lives, from days to seconds. As a noble gas radon can diffuse out of the thin film before decaying. Due to the very different half-lives this so-called emanation is very different for the three radon isotopes. Nearly all ^{222}Rn(^{226}Ra daughter,$T_{1/2}$ = 3.8 d) can escape before decaying, whereas ^{220}Rn (^{224}Ra daughter,$T_{1/2}$ = 56 s) and ^{219}Rn (^{223}Ra daughter,$T_{1/2}$ = 4 s) mainly decay still adsorbed. Alpha spectra presented clearly show these differences in the emanation factors. The differences have an important consequence when quantifying ^{224}Ra in the presence of comparable ^{226}Ra concentrations. Due to the strong ^{222}Rn (^{226}Ra daughter) emanation there is nearly no spectral interference from ^{222}Rn and its daughter products in the energy range of the alpha peaks from ^{224}Ra and its daughter products.

A hydrogeochemical study of thermal water (Geysers Hammam Debegh & Ouled Ali) using Toth's theory in Eastern Algeria

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A hydrogeological study of thermal water was carried out in Guelma region with reference to Hammam Debegh and Ouled Ali. The region in North-East of Algeria is characterized by mountainous terrain (i.e 1,411 m amsl, Mouhna Mountain). The region belongs to the Seybous basin with Mediterranean climate. The land cover is dominated by forest diversity with a complex geological framework due to the plate tectonics. The landscape is defined by outcrops of sedimentary formations from Triassic to Quaternary ages. Based on physical and chemical groundwater analysis; the focal point of the study was to identify flows of different hierarchy and define the actual recharge area of the two major springs located close to each other but with water of contrasting temperature and chemistry. Elements of the groundwater flow system's theory were applied to define their flow path. This was achieved by answering questions related to water chemistry evolution to understand groundwater behavior. Groundwater flow depends on gravity and cross formational motion at different space and temporal scales that are proportional to the configuration and dimensions of the topographic relief and stratigraphic conditions in human and geological time spans as defined by Toth. Such controls are used to explain the difference in water temperature of geysers near to each other. Results Interpretation from a Tothian perspective concluded that the distribution of thermal water is linked to deep contrasting regional flows, evident by conditions resulting from plate tectonics, where the chemical quality of thermal waters results from their flow path across various lithologies; their temperature is proportional to different travel depth due to the geothermal gradient. The difference in temperature, chemistry, and isotopes from one spring to another, permitted to identify recharge characteristics, this could imply to suggest the existence of different unit-basins as proposed by Toth.

Role of Uranium-bearing Brines Location in Controlling the Formation of Unconformity-related Uranium Deposits

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Uranium-bearing brines were present in both the sandstone layer and the basement unit at ore genesis time in the Athabasca basin, Canada, that hosts many large unconformity-related uranium deposits. In this study, a 2-D reactive flow modelling is conducted to examine how the location of U-rich brines impacts the uranium ore genesis. Numerical results from four numerical case studies indicate that more, larger, and higher-grade uranium deposits tend to form when the basement accommodates U-rich brines than when the sandstone layer accommodates U-rich brines. Also, uraninite tends to precipitate earlier with the basement serving as a major uranium source than with the sandstone as a major uranium source. The simulated uranium deposits are in the footwall of a faulted graphite zone and below the unconformity interface, where a considerable drop of oxygen fugacity, a temperature of 170-200°C, and a pH of 4.5-4.7 exist.

Salinity evolution of aquitard porewater associated with transgression and regression in the coastal plain of Eastern China

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Aquitards can preserve paleo-saltwater and have a long and profound influence on the aquifer groundwater, yet they have received less attention. Here we measure natural tracers, Cl^-, Br, δ^2H, and $\delta^{18}O$ in thirteen boreholes in three Eastern China coastal plains, Bohai bay, Laizhou bay, and Jiangsu area, to show the salinity origin and the timescale of the transport of porewater across aquitards. Porewater salinity showed spatial consistency of vertical distribution, that is, the higher Cl^- value was observed at the bottom of Holocene sediment in most sites, associated with Holocene transgression, and later porewater was partially flushed by freshwater during regression. This is evidenced by Cl^- and δ^2H mixing model. However, porewater can show ongoing evaporation to be brine near ground surface in some depression zone characterized by high salinity and depleted water isotopes. Deep saline porewater (depth 150-200 m) was observed locally, which is caused by the salinity input of adjacent aquifer where it is most likely a paleo-channel in preference to seawater intrusion.

The chloride transport simulations using the 1-D modeling approach showed that Cl^- distribution is controlled by alternating seawater and freshwater diffusion. Modeling results supported that diffusion is the dominant transport across aquitard with an upward velocity of 0.03 -0.9 mm/yr but indicated solute transport has also been affected by reversed advective flow in the areas where extensive pumping occurred in recent 60 years. The downward porewater velocity of 50 mm/yr and 63 mm/yr were derived for G1 and LZ12 boreholes, stressing the significant influence of pumping on the porewater salinity distribution.

The simulations suggested that the initial marine water was trapped Holocene seawater but experienced evaporation. The enriched Br^- in porewater may be as an indicator of ancient seawater. However, due to the different geological and climate conditions, the underground brine showed different salinities across the region.

The rise of global sea level in the Early Holocene has been recognized all over the world. The trapped seawater will still be present in low-permeability aquitard and leached into adjacent sediments. We emphasize that the redistribution of marine saltwater in the aquitard is a significant cause of groundwater salinization. Furthermore, the saltwater resulting from seawater intrusion into the aquitard can also become a long-term pollution source. Ancient paleo-channels, in particular, would be used as a priority outlet, resulting in seawater intrusion.

Differentiating Hydrothermal Source Rocks through Strontium Isotopes ($^{87}Sr/^{86}Sr$)-an Example from the Los Cabos Block, BCS, Mexico

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The use of strontium isotope ratios can improve our knowledge of hydrothermal reservoirs. The $^{87}Sr/^{86}Sr$ values from nine hydrothermal manifestations of the Los Cabos Block, a granitic batholith in the southernmost part of the Baja California peninsula (Mexico), were used to define endmembers and to recognize the potential rock type of the deeper reservoir. The $^{87}Sr/^{86}Sr$ signatures of nine samples resulted in a wide range of isotopic vales, ranging from 0.7042 to 0.7127, which indicates a geologically heterogeneous of the source rock. By comparing $^{87}Sr/^{86}Sr$ and (reciprocal) Sr concentrations, three end-members were identified and compared to the $^{87}Sr/^{86}Sr$ signatures of 24 samples reported for rock formations of the Los Cabos Block. This permitted to define the potential reservoir rocks of the deep reservoir: End-member A can be related to granitic rock (with $^{87}Sr/^{86}Sr$ values around 0.710), another (B) to amphibolic gneiss (with $^{87}Sr/^{86}Sr$ value of 0.7050 to 0.7070); and the third (C) is related to older silicic continental rock (with $^{87}Sr/^{86}Sr$ values of 0.7110 to 0.7130). The hydrothermal manifestations, situated along the San Jose del Cabo fault, show a diminution from the north (0.7268) to the south (0.7069), within a distance of only 5.3 kilometres. This may be caused by a change of the type of reservoir rocks (from granite via granodiorite to amphibolic gneiss) or may be the result of the mixing between thermal water originated from end-members A and B.

Numerical simulation of fluid flow and thermal transport in the context of enhanced geothermal potential with discrete fracture networks in the St. Lawrence Lowlands basin, Quebec, Canada

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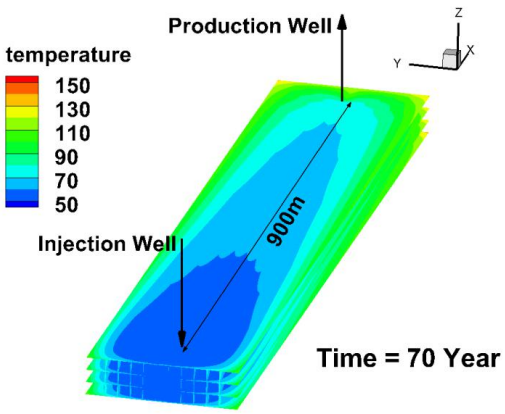
An enhanced geothermal system (EGS) consists of injecting water into deep sedimentary or basement rocks which have been hydraulically stimulated and withdrawing this water in other wells for heat extraction. Formations with sufficiently high temperatures at technologically and economically feasible depths can be viable sources of electrical energy production. Obtaining reliable measurements of deep subsurface temperatures remains an important challenge for EGS development.

The geothermal potential of the St. Lawrence Lowlands basin (Quebec, Canada), is here evaluated using numerical simulations and observed geological and hydrogeological data. A 3D conceptual model has been developed based on a detailed geological model of the basin, and the distribution of hydrothermal properties and radiogenic heat production at various depths has been obtained by laboratory experiments and well logs (Gamma ray, Density, Neutron Porosity and Sonic). Numerical simulations of the basin thermal regime under natural conditions were then conducted with the HydroGeoSphere 3D model assuming non-isothermal single-phase flow. The simulations produced heat flux variations at the base of the model which were within a realistic range and the simulated basin temperatures were consistent with the measured BHTs. The calibrated model was finally used to define the depths (areas) for which ground temperatures are expected to be higher than 120°C. Preliminary numerical results reveal that the areas with EGS potential in the St. Lawrence Lowlands basin are distributed at depths from 3.5 to 5.5 km extending from the northeast to southwest along the basin.

Subsequent conceptual 3D simulations at the local resource development scale were then carried out using the HeatFlow/Smoker model applied to a discretely-fractured porous medium to test thermal extraction efficiency. Fracture density is shown to control thermal exchange between the cold injection and warm extraction wells.



Groundwater discharge visibility and vertical flow in understanding recharge in western Tunisia

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Groundwater discharge zones, locally known as Chotts, are a major topoform feature in western Tunisia. Surface groundwater indicators plus relevant published data on regional hydrogeology of Chotts in Tunisian (and Algeria) are used as an alternative view of agreeable groundwater recharge-discharge processes along the regional flow system. Classic water-balance, geological framework, water chemistry, discharge-transit-recharge conditions support the existence of regional groundwater flowing through the Complex Terminal, and underlying Continental Intercalaire formations; flow that discharges in chotts, and the sea. The main recharge zones of this groundwater are claimed to be the Dahar Mountains of Tunisia, and the south of the Atlas Mountains and the Tinrhert plateau of Algeria. Chotts location occurs towards the coastal area, many with negative elevation conditions (-33m bmsl). The horizontal groundwater flow towards chott El Djerid (6,700 km^2) as well as to those in Algeria (Melrh, Merouane) shows human influence along its path. Chotts discharge water is with high salinity and temperature as in Chott Gharza. Surface indicators based on Tóth's theory were analyzed with hydrogeological data to understand the systemic connection along recharge, transit, and discharge zones. Results suggest the presence of contaminants (16.8 mg/L, NO3-N) produced by vertical downward flow in the transit zone evident in shallow wells. Uncontaminated water discharges in the chotts result of ascending regional flow with the highest values of lithium (0.22 mg/L) and temperature (33.6° C); and low NO3-N (4.6 mg/L). Findings suggest the importance of ascending flow in the chotts region is contrasting with that of lateral flow. A further systemic reviewing of scientific data and designing a widespread training scheme in groundwater flow systems understanding seems to be desirable, plus to have data collection and shearing of homologated concepts on groundwater flow systems in its 3D domain.

Using hydrogeochemical caracteristics to refine the conceptual model ofgroundwater flow in Wood Buffalo National Park, Canada

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Wood Buffalo National Park (WBNP), located in north-central Canada, is Canada's largest national park with an areal extent of 44,807 km^2. The pristine landscape exhibits some of the finest examples of gypsum karst topography of North America, extended salt plains unique in Canada, and rare wetland ecosystems, including whooping crane habitat. Due to its protected status and poor accessibility, the hydrogeology of the area has not been extensively studied. The objective of this study is to integrate a synthesis of hydrogeochemical and isotopic characteristics of springs and surface waters with prior conceptualizations of groundwater flow dynamics in the region.

Results reveal great variability in Total Dissolved Solids contents, ranging from less than 1,000 mg/L to more than 300,000 mg/L, with three major water types, Ca-HCO_3, Ca-SO_4, and Na-Cl, plus locally "mixed" waters. Brackish, Ca-SO4-type waters occur in multiple clusters across the area; the clusters coincide with outcrop areas of Devonian evaporites that were previously hypothesized as discharge areas of intermediate to regional groundwater flow paths. Saline, Na-Cl type waters predominantly occur along the central eastern boundary of the study area; this Salt plains region was previously described as a regional groundwater discharge area that overlaps anhydrite and carbonate-dominated bedrock formations. Fresh, Ca-HCO3-type waters that dominate the southern and much of the central region coincide with recharge areas delineated by others. Mixed waters illustrate localized mixing of the above basic water types across the study area. The observed hydrogeochemical characteristics are indicative of the scale of hypothesized flow systems, but modified by local and regional geology (e.g., presence of evaporite and halite-bearing strata).

The dissemination of the results is supported by the ENeRAG project funded by the European Union's Horizon 2020 research and innovation program under grant agreement No 810980.

What is the significance of incorporating flow systems in geofluid research? – Exchanging views from scientific basis to practical approach

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In the last decades, geologists recognized that the solid framework of the crust evolves through interactions with geologic fluids. Geofluids play an essential role in all geologic processes, such as the mobilization, transportation, and accumulation of matter and heat. Driving forces of regional fluid flow, like topography, tectonic compression, compaction, erosion, buoyancy, can operate together on a geological time scale. The permeability of the rocks may be able to maintain the fluid potential differences, thus enabling the flow systems to operate for even up to 10 million years. In addition, the fluid flow systems determine the evolution of the geological resources, such as groundwater, hydrothermal mineral and geothermal resources, and hydrocarbons. Moreover, they influence the consequences of human impacts on the environment, and their mitigation. In this presentation, we focus on some fundamental questions for example: i) How can the term “geofluids” be defined? ii) What are the basic differences regarding the perspective of the specific fields of groundwater, hydrothermal fluids, and hydrocarbon? iii) Why should geologists be encouraged to incorporate flow systems in their research on geofluids? iv) What is the significance of not only acknowledging the existence but also exploring the role of the flow systems in geofluid research? In this interactive presentation, we will attempt to find answers to these questions collectively. We demonstrate that understanding flow systems provides the scientific basis and a practical approach for all areas of geofluid research, from regional to local scale. This approach is used to develop the workflow guideline applied in the ENeRAG focusing on the coordinated exploitation and utilization of different geofluids and geological resources.

The research is supported by the ENeRAG project that has received funding from the European Union’s Horizon 2020 research and innovation programme under Grant Agreement No. 810980.

Assessing groundwater and seawater mixing using isotopes of H, O, Sr, S and Li in pockmarks with different degrees of groundwater influence at a submarine groundwater discharge site in Hanko, southern Finland

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A submarine groundwater discharge (SGD) site was found and studied between the years 2017–2019 near Lappohja in southwestern Finland. The site is connected to the First Salpausselkä ice-marginal formation on the Hanko Peninsula. Previous seawater radon (222Rn) measurements showed that the groundwater discharge largely takes place through pockmarks on the seafloor at ca. 10 m water depth and at ca. 200 m distance from the shoreline. Here samples of seawater and sediment porewater from three larger pockmarks and the local groundwater have been studied for multielement composition by ICP-MS/OES and for isotopic ratios of $\delta^{2}H$, $\delta^{18}O$, $\delta^{7}Li$, $\delta^{34}S$ and $\delta^{87/86}Sr$. The studied pockmarks, named here B, D and E, show different degrees of groundwater influence with E being inactive, B showing an intermediate groundwater influence and D showing a strong groundwater influence. The hydrogeochemical results confirm and refine the previous radon observations, and permit assessing conservative and non-conservative behavior of the studied isotope ratios in the groundwater-seawater mixing zone.

Evaluation of a natural uranium contamination of a riverbank filtered drinking water supply system

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Drinking water is frequently based on riverbank filtered systems. In addition, these types of reservoirs provide 90 % of perspective water supply systems, therefore their protection and knowledge of potential contaminants in water is essential. Natural contaminants can be radionuclides, which are monitored by screening methods. Hydrogeology has a crucial role in revealing the origin of elevated activity concentrations. This research presents a case study in Hungary where the drinking water supply is provided by bank filtered and karst wells. In most of the wells of the research area the gross alpha values are above the limit, 0.1 Bq L^{-1}. The aim of this study is to determine which radionuclides may cause the elevated radioactivity and explain their occurrence using the hydrogeological approach. The study revealed the correlation between the river water level fluctuation and the uranium content of the wells. The results of this study highlighted the transient nature of riverbank filtered systems, which should be considered in the monitoring and water supply strategy. Nevertheless, the study emphasizes the importance of considering the dynamics of groundwater and associated geochemical environment in addition to geological factors, when investigating the radioactivity of groundwater or other potential contaminants.

This study was supported by the ÚNKP-19-3 New National Excellence Program of the Ministry of Human Capacities, and József and Erzsébet Tóth Endowed Hydrogeology Chair. This study is part of a project that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 810980.

Isotopic data in groundwater-surface water interaction study for a MAR site characterization

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Viet MAR is a co-operation project among CEWAFO, SIHYMECC and GTK. It is financed by the Ministry for Foreign Affairs of Finland aiming at securing future freshwater resources in Vietnam with sustainable and environmentally friendly solutions such as Managed Aquifer Recharge (MAR).

The project focuses on two sites in the Binh Dinh province, South Central Vietnam. The Tan An site is located inland along river Kon, and the Phuong Mai site is located on a peninsula east to the Quy Nhon city. Waterworks at the Tan An site utilizes river filtration in water uptake. On the Phuong Mai peninsula, there exists a large pond and several springs that are largely unutilized for water extraction.

In Tan An, the river water and groundwater monitoring wells were sampled during rainy (November 2018) and dry (June 2019) seasons for δ^2H and $\delta^{18}O$ compositions. The results were compared with average isotopic Quy Nhon groundwater composition and annual average precipitation composition of nearest GNIP station (Dong Hoi, 2016-2018). Annual precipitation and yearly average of Quy Nhon groundwater have similar compositions meaning local groundwater is formed mainly of local precipitation. Dry season river sample resembles closely groundwater meaning groundwater recharges the river during the dry season. Rainy season river sample and some groundwater samples are below LMWL showing evaporation and possible groundwater - surface water interaction.

In Phuong Mai, the annual precipitation and yearly average of the groundwater compositions resemble closely each other and plot on LMWL. Groundwater samples showed no signs of evaporation or surface water interaction.

Although the two sampling campaigns are not very representative and are only showing the hydraulic character of the examined periods, seasonal variation in δ^2H and $\delta^{18}O$ compositions was revealed. River filtration dependant aquifer storage and recovery requires more monitoring to understand aquifer characteristics and ensure feasible MAR.

Hydrogeochemistry of warm water inflows in deep tunneling – technical risks and geothermal chances. Examples from the Swiss Alps

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Deep tunnels in mountainous regions cause groundwater inflow from rocks above. The inflow is governed by the pronounced relief of the mountain water table. The waters can create technical problems during tunnel construction, which are mainly warded by concrete injections. The chemical signature of the inflowing waters usually reflects the composition of the country rocks; local differences can occur in permeable fracture zones. Waters with high chloride and/or sulphate contents can attack the concrete lining and its steel reinforcement installed to stabilize the tunnel. Concentration limits (e.g. 600 and 2000 mg/l SO4) and the properties of concrete to cope with such waters are defined in various norms. At tunnel sections with such inflows, correspondingly prepared concrete is sprayed and lined.

Inflowing waters and country rocks are usually in thermal equilibrium. Water temperatures can be high (up to >50 °C), especially in deep tunnels below the Alps. The waters are collected and channelled to the portals. In Switzerland, environmental regulation limits the discharge (l/s) into nearby rivers; in such cases cooling ponds or even cooling towers are needed, at least during the tunnel construction phase. Therefore, energetic use for space heating, greenhouses, fish farming at the portals is more advantageous and can be profitable. Examples of hydrochemical characteristics and tunnel cementing measures on one hand, and of geothermal utilizations at portals on the other, are presented from the Gotthard (76 km) and Lötschberg (36 km) Base Tunnels, Swiss Alps.

Origin of saline groundwater within fractured crystalline aquifers of the Canadian Shield in Eeyou Istchee James Bay: Case study of Eléonore Mine

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Saline groundwaters are commonly found in deep crystalline aquifers of the Precambrian Canadian Shield. The hydraulic gradients induced by mining activities can promote their migration and mixing with shallow aquifers. Fitting in this context, this study aims to investigate the origin of salinity and mixing dynamic of groundwater within the crystalline aquifers of the Canadian Shield at the Newmont Éléonore site, an active underground gold mine located in Eeyou Istchee (James Bay area, Northern Quebec). Eleven groundwater samples were collected at depth from 80 m to 830 m within the mine galleries. Chemical and isotopic analyses included major, minor, and trace inorganic constituents, stable isotopes of water ($\delta^{2}H$, $\delta^{18}O$), $\delta^{37}Cl$, $\delta^{81}Br$ and $^{87}Sr/\ ^{86}Sr$. The preliminary results show that shallow groundwaters (depth < 100 m) are fresh (salinities of 0,05 g/l to 0,2 g/l) and present Ca-SO_4, and Ca-HCO_3 water types. The intermediate zone (200 m - 500 m) presents groundwater with various water types (Na-Cl, Na-HCO_3, Na-HCO_3-Cl) and intermediate salinity (salinities of 0,2 g/l to 0,33 g/l). The deep groundwaters (770 m - 830 m) are saline (salinities of 1,9 g/l to 3,33 g/l) and present a Ca-Na-Cl water type. Groundwaters found in the intermediate depth zone present compositions that suggest the mixing of fresh and saline groundwaters. The increasing concentrations of Cl^{-}, Na^{+}, K^{+}, Ca^{2+}, and Mg^{2+} with depth could be derived from (1) the intensive water-rock interactions with minerals (2) the migration of deep brines, and (3) a possible mixture with infiltrated sea waters since the study site is located at the limit of the marine transgression of the former Tyrrell Sea (last deglaciation). The groundwater inorganic constituents will be interpreted together with the isotopic data ($\delta^{2}H$, $\delta^{18}O$, $\delta^{37}Cl$, $\delta^{81}Br$, $^{87}Sr/\ ^{86}Sr$) to elucidate the origin and processes that generated salinity in this fractured bedrock aquifer.

Investigating transport and fate of herbicides in two lysimeters and potential impacts to groundwater

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Intensive agricultural activities that lead to the release of agrochemicals like nitrate or pesticides, pose significant threats to groundwater. In this study, we investigate the transport and fate of four herbicides (terbuthylazin, metolachlor, prosulfuron, nicosulfuron) and some of their metabolites in a 3-years lysimeter study. The studied lysimeters contain soil cores dominated by sandy gravel (Ly1) and clayey sandy silt (Ly2) and are both vegetated with maize. As a first step, we have characterized water flow in the unsaturated zone of the lysimeters by stable water isotopes coupled to lumped-parameter modelling (LPM). In addition, numerical water flow simulations were carried out using HYDRUS-1D for LPM model validation, as well as for investigating mobile-immobile water interactions and preferential flow in single and dual porosity approaches. Furthermore, different assumptions concerning root water uptake and root growth were compared. The second step involves the modelling of reactive herbicide transport and chemical fluxes in lysimeter outflow, which would eventually reach groundwater. Aims of this study include an improvement of process understanding, by identifying processes that contribute to the observed herbicide peaks in lysimeter outflow water and by determining dynamics and rates of these processes. First results of modelling and analysed stable carbon isotopes (δ13C) of TBA and metolachlor in outflow water indicate a significant contribution of biodegradation activity, however sorption processes are expected to dominate herbicide fate in the lysimeters. The implementation of root water uptake could improve the explanation of observed lysimeter outflow rates. The dual porosity approach for flow and transport simulation led to a significant improvement, in particular for Ly2. Our (further) developed model approach can be used as a strong tool for supporting decision-making that aims at minimizing impacts of agrochemicals to soil and groundwater.

Evaluating the relevance of topography driven groundwater flow in a low temperature geothermal system in the Julian Alps, Slovenia

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Studying dynamics of the regional groundwater flow system from the recharge areas to the discharge zones is probably the most efficient way to answer some fundamental hydrogeological questions. Namely these are: what the geometry of the groundwater circulation system is, where are the main flow paths, what is the natural temperature distribution in different geological formations and what is the intensity of the thermal flow. If those questions are properly addressed, they can significantly contribute to planning the sustainable use of thermal water.

This study is focused on the low temperature geothermal system in the karstic-fissured aquifer located in the eastern Julian Alps, in the surrounding of Bled Lake (Slovenia). The occurrence of such systems is common in the Alps and is defined by a series of specific hydrogeological conditions such as: large vertical component of fluid flow, relatively significant differences in altitude between the recharge and discharge areas, and the concentrated ascending of heated water to the surface. Previous hydrogeochemical investigations have proved that thermal outflow in Bled with a temperature between 19 to 23 °C is determined by the presence of deeper water circulation system. Here the dissolution of calcite and dolomite is the main hydrochemical process affecting chemical components of natural groundwater flow recharging from higher mountainous area.

In this study basin-scale groundwater level configuration and flow patterns are evaluated based on the interpretation of hydraulic, chemical and temperature data of springs of the area. It was showed that the addressed fundamental hydrogeological questions could be answered by applying the concept of regional groundwater flow also in the Bled case. Data interpretations indicate the presence of groundwater fluxes with shallow pathways, while the lukewarm flow in the karstic-fissured aquifer can be characterized by longer transit times and deeper pathways.

This study was supported by the Slovenian Research Agency (ARRS) in the frame of the young researcher programme and programme group P1-0020, and Bilateral State Scholarship for student mobility approved by Tempus Public Foundation.

Maximum concentrations of microelements in mine waters of the South-Eastern Donbass and their influence on the aeration zone of adjacent landscapes

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Mineralization of Donbass mine waters and the content of trace elements in mine waters and rocks increases in the southeast direction. Maximum mineralization of mine waters (g/l): Kapustina mine (up to 34.7), Proletarskaya (up to 23.5) and Lugansk mine (up to 9.5). Maximum concentration of trace elements (g/l): Br-0.137; Li-0.0065; Ba-0.019; Sr-1.294; Ti-0.019; Mn-0.097 (Kapustin mine). pH varies from 5 to 9, depending on the mineral composition of the host rocks. Concentration (g/l): sulfates in wastewater is 0.234-1.988 (max-3.868), chlorides-0.080-22.002.

With wastewater from coal mines and sources from dumps, the following enter the surrounding landscapes: Ti, Mn, Li, Br, Be, Cd, Pb, Zn, Ag, Ba, As, Hg, S, Ge, Ga. The dissolution of trace elements of the host rocks is caused by a change in the thermodynamics of the massif - a high chloride content in these areas (up to 5-20 g/l) and a temperature of about 40°C, at which coal seams are developed.

The influence of mine wastewater on the aeration zone of this region showed that the natural system was capable of self-controlled processes - self-cleaning of the surrounding landscapes due to the presence of geochemical barriers in the aeration zone, which accumulated up to 80-90% Pb, Zn, Ni, Ag, Mn, As, Hg, S, Ge, As and other metals that appeared because of coal mining. The aeration zone of aquatic landscapes in this region has three geochemical barriers, and alluvial landscapes have eight geochemical barriers, which are accumulators of heavy metals and microelements.

Conclusions:

1. Depending on the mine field, mine waters can be used as hydromineral resources of metals and rare earth elements.
2. Depending on the specifics of the aeration zone, it is advisable to store overburden at landfills, where the aeration zone has the maximum number of geochemical barriers to control the processes of technogenesis and reduce risk zones for the environment and the recharge zone of alluvial aquifers.

Hydrogeochemical characterization of the regional groundwater flow systems in Southern part of Pannonian Basin (Serbia)

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As an integral part of the Alpine orogenic system with a complex geologic and tectonic evolution, the Serbian part of the Pannonian Basin (PB) is characterized by the formation of a complex hydrogeological framework. A regional hydrogeological conceptual model has been supplemented with hydrogeochemical indicators to understand the relationships between deep geofluids (thermo-mineral groundwater) and the geological framework. The primary delineation of hydrogeological systems was based on finding geofluids with similar rare earth element (REE) patterns and radioactive isotopic composition using multivariate statistical analysis. A better understanding of the regional geological and structural context has been reached with hydrogeological interpretation of regional seismic profiles traversing the Serbian part of the Pannonian Basin and adjacent area in its margin.

Regional groundwater flow developed in deep Miocene marine sediments is characterized with MREE enrichment and large positive Eu and Y anomalies, related to geofluids of reducing and high-temperature conditions. In some cases, high gross beta activity may indicate the inflow of geofluids from the crystalline basement.

At the southern margin of the PB, the complex of horst systems (Miocene S-type granite) of the Vardar zone enabled the formation of sub-thermal low-mineralized REE enriched geofluids with a relatively flat pattern, and with detected Th concentrations (above median values based on 193 data).

REE signature was recognized in mineral waters of crystalline shists where HREE enriched pattern is significant. These geofluids are characterized by elevated gross alpha and beta activity concentrations, which emerged in a regional fault system well known by CO_2-rich geofluids at the contact of the Vardar zone and Serbo-Macedonian Massif.

The obtained conceptual regional hydrogeochemical model outlined the regnant factors that control geofluids hydrochemistry as a crucial point in further research of thermo-mineral waters.

Transient Numerical Modelling for the Karst Aquifer of the Transdanubian Range between 1951-2030

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The karst aquifer of the Transdanubian Range mainly consisting of Upper Triassic carbonates is the major karst water resource of Hungary. The overlying layers contain significant amount of bauxite and coal, mining operations began to apply dewatering technology from the 1950s. By the 1990s water extraction resulted in a lowered karst water level, also discharge reduction and disappearance of some karst springs. Due to environmental damage, economic and political reasons, bauxite, and coal mining ceased. The karst aquifer began to recover, almost reached its natural state by now. The recovery process caused problems mostly in urbanized areas. Investigation and prediction of adverse effects of these processes is an important task for water management.

Regional numerical modelling of the complete karst water level lowering, and recovery process was possible by the availability of a dataset consisting of water production rates, water level and spring discharge data covering the last almost 70 years. The numerical model was created in the framework of an EU-supported KEHOP project, led by the General Directorate of Water Management, implemented by SMARAGD-GSH Ltd.

The aim of the numerical modelling was primarily to answer water management questions, thus it not only covered the recent period, but was also configured to forecast for the next decade, until 2030.

Based on the prognosis, it can be decided where the ongoing recovery causes risks, where drainage system overload can occur, and whether the increasing water demands cause environmental problems as before.

The spatial and temporal simulation of the changes in the karst water level was performed with a 3D finite element numerical transient model, using Feflow 7.2. The model area is 17,000 km^2.The time-varying input data in the model are the recharge rates, resulting from a HELP model calculation, the water production rates and the karst water levels (68 years of data from 1243 production and 224 monitoring wells).

Cave sediment analysis of Molnár János Cave – Hungary

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The deposition of sediments in a cave reflects the historical processes that can be studied to understand the climatic and landscape evolution of the area, including past local and regional environments (1). In caves, sediments are preserved based on their environment conditions, making them a reliable source of historical data (2). The Molnár János Cave (MJC), located in Budapest, Hungary, is considered to be a hypogenic cave, isolated from large-scale interference from the surface. Since the cave is supposed to be formed by mixing corrosion, and we can observe only very low flows in the submerged cave passages we can expect that the sediments are composed from the dissolution residues of the rocks in the immediate vicinity. Our preliminary investigations however found that at some sampled sites the sediment is not chemically similar with the rock dissolution residues. We noted that some sites display a layered sediment structure indicating a periodically changing flow in the past. The presence of fast flows can also be postulated from the large average size of the sediment particles in some layers. The presence of these flows in the past extends our knowledge about the formation of the cave and opens the possibility that the sediment samples carry historical information from the surface conditions at the time of deposition.
Our study focuses on the chemical composition of sediments, as a historical record of the evolution processes that formed one of the largest active hydrothermal caves in the world and environmental changes above the cave.

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The prospects to use thermal waters in heat-and-power engineering

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The bowels of the earth in Georgia have rich deposits of underground thermal waters, which are widely applied in the economics of the country, starting from heat-and-power engineering and agriculture and through medical-recreational complexes. The long studies accomplished by the Georgian geologists have proved that the great supplies of thermal waters in our country come from a thick Lower Cretaceous carbonate stratum of the Mesozoic Age. Thermal waters opening in boreholes are common in all corners of Georgia, though particularly rich in this respect are Samegrelo and Abkhazeti Regions. Outstanding thermal water deposits in the two Regions, with their temperature often exceeding 100°C, are Kvaloni, Okhurei, Senaki and Kindghi deposits where strong water-and-vapor fountains erupt from the boreholes.

Hydrothermal recourses in Western Georgia

Role of coupled fluid flow and heat transfer in synthetic and real groundwater flow systems

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Two-dimensional numerical simulations were carried out in order to elucidate the mechanism of the coupled fluid flow and heat transfer in synthetic and real groundwater flow (GWF) basins.

Based on a theoretical concept, effects of geothermal gradient, regional relief, model depth and anisotropy of hydraulic conductivity were investigated on groundwater flow pattern and temperature field. Using the thermal Rayleigh and the modified Péclet number, the role of heat advection and thermal buoyancy was separated in GWF system. The thermally driven free convection is facilitated by higher geothermal gradient and greater model depth, while increasing regional relief and anisotropy intensify the effect of forced, water table-controlled convection. Such a theoretical approach has been applied in hydrogeology modelling; therefore, it was demonstrated for the Buda Thermal Karst (BTK), Hungary.

Three main types of heat transport phenomena (heat conduction, advection, thermal buoyancy) were examined to highlight the role of different driving forces of GWF. The Nusselt number and the recharge rate were used to confirm the numerical method, and to reveal the dominant driving force. Although the radiogenic heat production and the hydraulically conductive faults have only a minor influence on basin-scale GWF system, boundary conditions applied for fluid flow and heat transfer significantly affect the numerical results. The results from numerical simulations were compared with the available temperature data. In each scenario, time-dependent mixed thermal convection evolved in the thick, karstified Triassic carbonates of the BTK.

This research is a part of a project that has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 810980. The research was prepared with the professional support of the Doctoral Student Scholarship Program of the Co-operative Doctoral Program of the Ministry of Innovation and Technology financed from the National Research, Development and Innovation Fund.

Hydrogeochemical investigation of medicinal water producing in the Hospital of Parádfürdő

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The use of alum-containing ferrous medicinal water in the hospital of Parádfürdő is a unique example in Hungary because the water used for therapies is produced by leaching of limonitic kaolinitic pyrite-bearing sulphatic dacite breccia. We had the opportunity to work with the hospital's experts to find out how the pretreatment of the rock can affect the production of medicinal water.

We investigated two modifications in the production of medicinal water, the size effect of the leachable rock and the mixing of the leaching solution. The original size (diameter 80-120 mm) of the rock was reduced by crushing (diameter 0-25 mm) to investigate the leaching enhancing effect of rock surface enlargement. During the mixing treatment, the air was blown in the reactors which was also a leaching enhancing effect. Three replications were carried out in each treatment, where the pH, temperature and EC change were recorded during the 144-hour long investigations.

In the initial sampling points of the experiments, we found differences in the measured values of the parameters between the treatments, but these differences were not significant. However, medicinal water production in the hospital is a long-term process, so time is not a limiting factor, the treatment of the rock cannot significantly improve the leaching under the given conditions.

Fluid inclusion study of zoned garnets from the skarn deposit of the Recsk Ore Complex (NE Hungary)

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The NE Hungarian Paleogene Recsk Ore Complex is famous for its porphyry Cu and epithermal Cu-Au mineralizations, but less known polymetallic skarn and carbonate replacement ores also appear (Baksa, 1986).

This research provides new information about the fluid responsible for the sphalerite, galenite, chalcopyrite mineralization of the distal skarn. This skarn is composed of andradite, diopside, tremolite, epidote, zoisite, anhydrite and calcite, but rare brucite, monticellite, perovskite, tochilinite/valleriite and alabandite also occur. Fluid inclusion study in early garnet and late calcite revealed the presence of groups of (P) LV inclusions in the core of garnet and in calcite, far from any secondary planes. In the outer zone of garnet, primary (P), elongated LV inclusions occur. The uniform L:V ratio suggests entrapment from a homogenous parent fluid. Fluid inclusion microthermometry on P type inclusions of garnet (n=13) provided homogenization temperatures (Th) of 330-354°C, and salinities of 10.73-5.56 NaCl eqv. wt%, based on final ice melting temperatures. The P type inclusions of the outer zone (n=19) showed Th=285-316°C and the calculated salinities are 9.21-4.03 NaCl eqv wt%. These Th data are typical in garnets of Cu-Zn skarn deposits (Meinert et al., 2005). Preliminary fluid inclusion study of calcite (n=2) showed Th=177-220 °C and calculated salinities were 3 and 2.4 NaCl eqv wt%. The observed eutectic temperatures (-23)-(-18,5°C) suggest a NaCl-H2O system. The fluid inclusions do not have measurable gas content, based on Raman spectroscopy.

Due to homogeneous entrapment, the measured Th values are equal to minimum formation temperatures. Thus, decreasing temperature and salinity are observable from the core of garnet through its rim, till the formation of late calcite. The ore minerals crystallized after the garnet, but before the calcite. This suggests that the dynamically changing fluid conditions contributed to the ore mineral precipitation.

The study is supported by the ENeRAG project that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 810980.

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Impact of flooding pattern changes and human activities on the ecohydrology of the Cerkniško Polje, Slovenia

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Cerkniško Polje has more than 300 years history of scientific exploration, where different aspects have been taken into account, e.g. studies of flooding dynamics, underground flow directions, quality and quantity of water, biodiversity of flora and fauna, human adaptation to flooding etc. These topics are now being brought together in a multidisciplinary ecohydrological study of the polje, where the main focus is to relate the flooding dynamics with habitat types and land use. For this purpose, numerous field measurements of hydrological parameters (water level, flows, temperature, conductivity etc.) and water quality monitoring for nutrients are taking place on up to 40 locations (springs, swallow holes, caves). Additionally, analysis of remote sensing of satellite and aerial images will be done in order to characterize the land cover changes. Data for more than 60 years of continuous hydrological and meteorological measurements and detailed map of habitat types from 2009 will also be used.

Initial analyses has revealed notable change in the flood dynamics over the past decades which appears to be linked to both climate changes (distribution of the rainfall) and human construction activities, including regulating of river beds, widening of swallow holes, construction of dams, etc. Land use changes, such as intensity, frequency and extent of harvesting also need to be considered. All these factors result in shorter duration and smaller extent of floods and consequently the ecohydrological conditions for the different habitats. Rich biodiversity is one of the most recognizable elements of the Cerkniško Polje but due to changeable flooding pattern different composition of plant species and some disturbances in fish and bird living cycle have already been noticed.

Acknowledgement: *This study is taking place within the project "Evaluating the ecohydrological dynamics of the Cerkniško Polje intermittent lake using a multidisciplinary approach", no. Z6-2667 and Karst Research programme (P6-0119), financially supported by the Slovenian Research Agency.*

Tracing groundwater recharge using meteoric isotope signal of deuterium excess

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Isotopic deuterium excess (d-excess) signal was used to evaluate the periods and zones of groundwater recharge in relation to the water quality in the unconsolidated glaciofluvial Karhinkangas esker aquifer, western Finland. The d-excess parameter is derived from the isotopic composition of oxygen and hydrogen and provides information on primary sources and secondary processes related to the groundwater recharge. The composition of oxygen and hydrogen isotopes and the physico-chemical parameters of the groundwater were determined seasonally both in longitudinal and vertical directions. Geochemical data were supported by the isotopes of local precipitation and continuous groundwater table and soil moisture measurements. Isotope data were processed by interpolating the d-excess in space and time and modelling the relative retention time of water percolation from soil surface into groundwater system based on phase-shift method by meteoric d-excess signal inherited from the precipitation. The results highlight the aquifer zones with high melt-water percolation and/or infiltration of surface waters. Here, the meteoric seasonal trend of d-excess was best preserved which enabled evaluating the retention between precipitation and groundwater recharge. The analysis suggests that recharged rainfall footprint is detected in groundwater roughly in a year.

Geothermal potential assessment of West Georgian Lowland

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West Georgia is rich in natural thermal waters and has a long history and traditions in their exploitation. These water resources have been used locally for balneological purposes only.

The increasing exploitation caused decrease in pressure and flow rates of wells. Due to the abovementioned circumstances, it became necessary to study the thermal water resources on the territory of West Georgian lowland.

In order to determine the hydraulic parameters of aquifers (hydraulic conductivity, transmissivity, etc.) hydrodynamic tests - closing/opening tests correspondingly were carried out on the out-flow of selected wells or pumping-injection tests on the negative wells; and their influence on the other wells (interference) were determined too. The heat flow and major ions composition of thermal water were studied as well.

For the realization of numerical model by software "Feflow", using existing and newly obtained data a conceptual model of thermal water aquifer was created, that implies the description and outlining the recharge and discharge areas, property of aquifers.

Numerical model defined hydrothermal resources, analyzed the possibility of creation of geothermal circulation systems, on the base of a pair of production and injection wells, to keep pressure in aquifer and avoid its total depletion. It will help to replace the traditional heat supply of the area with geothermal one in future.

Is proppant embedment a real phenomenon in the case of Upper Pannonian unconsolidated and friable sands?

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The loss of permeability in the near-wellbore region is commonly referred to as formation damage in the petroleum industry and may be caused by several factors including physical, chemical, physicochemical phenomena and biological activity (Chivan, 2007).

For the long-term economical operation of geothermal reinjection wells, the prevention of the reservoirs from formation damage is crucial. A feasible way to reduce mechanical formation damage phenomena during the reinjection of cooled thermal water is the application of frac&pack well completion technology due to the increased rock surface where the water can infiltrate into the formation.

As the largest Pannonian sedimentary deposit in the Carpathian Basin, the Upper Pannonian Újfalu Formation is the most important thermal water reservoir (Szanyi et al., 2015). Since the formation is characterized by poorly cemented, unconsolidated siliciclastic sediments it is raises some questions about how the fracture conductivity is affected by the embedment of proppant.

For the understanding of how the proppant pack behaves in these types of formations, long-term conductivity measurements were carried out in the laboratory under reservoir conditions using unconsolidated Upper Pannonian rock samples.

In conjunction with the long-term proppant conductivity measurements, a comprehensive characterization of the proppant was done including proppant density, crush test, grain size, and grain shape analysis. The embedment of the proppant grains was studied with 3D scanning and SEM images.

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Natural Uranium Contamination in Groundwater – Understanding the Mobilization and Transport Processes with the Help of Hydrogeology and Geochemical Modeling

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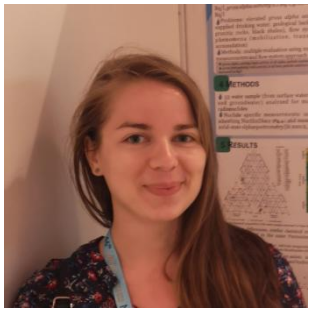
During drinking water quality monitoring, gross alpha activity above the 0.1 Bq L^{-1} limit was measured in several drinking water wells screened into a thick Pannonian sandy aquifer in the foreland of a granitic complex in Hungary. To assess the possible health risk arising from the radionuclide content of drinking water and to understand the natural radioactivity phenomena in this area, a complex hydrogeological, geochemical study was compiled. Nuclide-specific measurements were involved and ^{234}U+^{238}U (up to 753 mBq L^{-1}), ^{226}Ra (up to 695 mBq L^{-1}) and ^{222}Rn (up to 314 Bq L^{-1}) activities were determined. Based on the results of the regional-scale hydraulic evaluation, the field and laboratory measurements, a close correlation between the dominance of recharge regimes and local flow systems and elevated uranium activity was found. To support this interrelationship, and better understand the mobilization and transport processes, geochemical modeling using PHREEQC code was applied. It is concluded that the joint application of nuclide-specific measurements, hydrogeological approach and geochemical modeling can support safe drinking water management and risk assessment when dealing with the excess of radionuclides in groundwater-derived drinking water.



This topic is part of a project that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 810980. This study was also supported by the ÚNKP-17-4-III-ELTE-73 New National Excellence Program of the Ministry of Human Capacities (Hungary). The results here presented have been developed in the frame of the MIUR Project "Dipartimenti di Eccellenza 2017—Le Geoscienze per la società: risorse e loro evoluzione". The conference participation was subsidised by the Talent Support Council of ELTE Eötvös Loránd University, Budapest.

Impact evaluation of persistent organic pesticides on the groundwater by an innovative ASTR technology using probabilistic modelling

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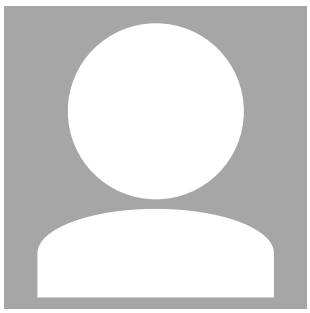

Sustainable management of groundwater by strategical use of managed aquifer recharge (MAR) methods are of vital importance to society and the environment to secure freshwater availability with the advancement of climate change. In Nanoor, Birbhum, West Bengal, a part of the Indo-Gangetic semi-confined alluvial aquifer, observed a steady groundwater level decline due to irrigation withdrawals. An innovative aquifer storage, transfer, and recovery (ASTR) system operated based on the principle of siphon, one of the methods of managed aquifer recharge (MAR) is installed in the selected region to counter the alarming levels of groundwater depletion. The ASTR system injected surface runoff at a rate of 30 m^3 per hour through an injection well of 0.05 m diameter. This study used a statistical method to evaluate the impact on persistent organic pesticide concentrations at the local-scale groundwater system determining the performance of the developed ASTR. There are observed changes in the pesticide concentrations with highly variable source water in a year-long monitoring process. This study is conducted by identifying the organochlorine pesticides – HCH and its isomers, DDT and its metabolites, endosulfan and its isomers, aldrin, dieldrin, endrin and heptachlor in the source water, recharged water, and groundwater (before and after recharge episodes). Following the local groundwater flow direction, the statistical analysis showed an overall attenuation of 40 percent in the concentration of the targeted pesticides after the recharge events from 2nd day to 20th day. Thus, the ASTR system reduced the overall concentration of the persistent organic pesticides due to high dilution rate at the local-scale groundwater system.

Mesoscopic observations of fluid-rock interaction at the pre-Deccan Basement rocks up to 1500 m depth in the Koyna Intraplate Seismogenic Zone of India

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The Koyna seismogenic region located in the stable continental part of the Deccan Volcanic Province has been experiencing shallow but recurring seismicity during the past five decades since the impoundment of the Shivajisagar reservoir created by Koyna Dam (~193 km from Pune city, Maharashtra) in 1962 which has been amplified after the establishment of Warna Reservoir in 1985. The Precambrian basement rocks in the area composed of granite gneisses are overlain by several layers of basaltic lava flows of Deccan Traps comprising massive and vesicular and/or amygdaloidal parts. The representative core samples collected from two boreholes KBH-1 at Rasati (17.377 N, 73.741 E) and KBH-3 at Kundi (17.082 N, 73.683 E), near the Koyna and Warna Reservoirs, have been studied mesoscopically as a part of MoES (Govt. of India) sponsored project. In addition to the accessory minerals, several phyllosilicates, carbonates, and highly oxidised minerals have also been noticed at altered and fractured zones in the pre-Deccan basement. Extremely friable nature of the massive granitoids at several depths e.g., 936.76 m, 1073.75 m, 1145.61 m, 1201.3 m and 1308.61 m have been inferred. Also, at 1027.86 m depth a greenish tint of *secondary mineralisation (Chlorite/epidote)* and at depths of 1153.78 m and 1286.04 m large scale *calcification* have been observed. Evidence of chemical alteration and precipitation of phyllosilicates and *displacement along the fractures* as a result of fluid induced slippage have been noticed in the core samples at a few places. The friable nature of rocks indicates the long-term interaction of fluid entered into the subsurface and causes generation of secondary minerals e.g., clay minerals. Fractures are noticed frequently throughout the basement, which provide water/moisture propagating channels. Actually, the vesicular parts of the overlying basalts here primarily act as the medium for infiltration of the reservoir water which after reaching the basement starts to propagate through the network of fractures and subsequently results incipient alteration in the massive Granitoid basement. Thus, the infiltration of water produces the slip surface in the basement rocks and helps to reactivate the existing faults in the region. All these mesoscopic observations on the basement rocks emphasize the evidence of fluid-rock interaction at shallow crustal level and generation of slip surface which ultimately triggers the recurring seismicity in the stable continental region of Koyna.

Fig 1. Greenish tint of Secondary mineralisation at 1027.81 m depth (KBH-1)

Fig 2. Incipient Carbonate at 1153.78 m depth (KBH-1)

Fig 3. Fracture displacement at 936.84 m depth (KBH-3)

Estimating surface water – groundwater interactions using a multidisciplinary approach in Río Acomé Basin, Guatemala, Central America

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Water scarcity during the last years has highlighted the importance of sustainable integrated water resources management in the Pacific Coast of Guatemala, an intensive agriculture region. As a result of climate change, scarcity events are expected to increase in both frequency and intensity, putting immense pressure on surface water and groundwater resources. Río Acomé Basin is facing a water storage deficit and its main stream (Acomé river) has been drying up during the last consecutive dry seasons. A good understanding of surface water - groundwater interactions is needed as the first step towards improved sustainable management and to build resilience against extreme events. Therefore, in this study Acomé river and the shallow aquifer of the basin are being investigated. In addition, agriculture lagoons have also been taken into consideration. Covering an area of 2.6 M m2, these machines dug lagoons are widely used for irrigation purposes. Unfortunately, the environmental impacts of these lagoons are unknown and thus need to be analyzed. To investigate these interactions, three approaches are being applied: (1) remote sensing, (2) piezometric analysis and (3) hydrochemistry. Sentinel 2 and Landsat 8 datasets were used for a preliminary delineation of critical areas. Groundwater levels and river discharges were analyzed using spectral analysis; the fluctuation period and time lag of groundwater levels with respect to the Acomé river were estimated. The time lag and the fluctuation period present an increasing trend as the distance from the river channel increases. Field water chemistry parameters were measured in 71 water body points in three different water bodies. In addition, 30 samples were collected to analyze major ions and stable water isotopes. Indicators of surface water - groundwater interactions determined through this study will contribute towards the development of an improved and climate-resilient local groundwater management system for the basin.

Groundwater flow models of the glacial aquifers at Lahti and Mikkeli sites, southern Finland

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In the ongoing RAINMAN project, three-dimensional groundwater flow models are developed for the complex glacial aquifer system in Lahti and Mikkeli sites, southern Finland to evaluate the sensitivity of the aquifers to climate change. The flow models are developed in the contexts of natural groundwater recharge, surface water-groundwater interactions and urbanization using the UZF1 model package coupled with the three-dimensional groundwater flow MODFLOW model to simulate water flow from the unsaturated zone to the aquifer. The snow and PET models are used to calculate the surface water availability for infiltration from the precipitation data used in UZF1. Infiltration rate, flow in the unsaturated zone and groundwater recharge are then simulated using UZF1. In the lake shore, the River (RIV) package is used to estimate the surface water-groundwater interactions through the lakebed infiltration. The calibrated simulations of the current data in both the steady- and transient states will be applied later with the climate change scenario RCP 8.5 data with different stress periods. The RAINMAN project (Towards higher adaptive capacity in urban water management) is implemented with the support of the South-East Finland – Russia CBC 2014-2020 programme funded by the European Union, the Russian Federation, and the Republic of Finland.

Impacts of atmospheric nitrogen depositions on ecosystems and groundwater resources

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Nutrients that fall on the ground from the atmosphere represent a minor component of the total nitrogen (N) input to soils, especially when compared to agricultural, civil and industrial inputs (i.e., sewage treatment plants or sewage systems, fertilizer, and manure applications). However, the atmosphere can be a significant source of nutrients that may even lead to an excess of nutrients with respect to the critical loads sustainable by ecosystems and affect natural background values of contaminants in subsurface environments (i.e., groundwater) in non-pristine areas.

A monitoring experiment was set up to collect wet atmospheric depositions in a human impacted area with multiple land uses and different land covers. Rainwater collection was executed in the surroundings of Milan, in northern Italy, starting from February 2017 to February 2019. After collection, samples were analysed for pH, electric conductivity, ammonium, nitrate, nitrite, major cations, and major anions.

The results show that N compounds, as nitrate and ammonium, are always the most abundant components in rainwater samples. The presence of N compounds and their temporal variations in rainwater are consistent with pollution coming from local anthropogenic emission sources of nitrogen oxides and ammonia, related to the use of the heating systems in the cold seasons and the spreading of fertilizers and manure on agricultural fields. Consequently, the total amount of N wet depositions range between 14 and about 30 kg/ha·yr in the study area.

As leaching of N compounds from soils increases at deposition rates higher than about 10 kg(N)/ha·yr, this work suggests that in a highly vulnerable zone the N atmospheric input can reach up to 18 % of the annual maximum amount of N from organic manure established by national and supranational regulations (i.e., Nitrate Directive, 91/676/EEC), thus strongly affecting the natural background values of contaminants in groundwater.

Complex flow fields due to different fluid driving forces in large sedimentary basins – Pannonian Basin, Hungary

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Groundwater flow can be generated by several driving forces including gravity. While gravity is the most common force, overpressure due to tectonic compaction or compression, underpressure, or variable density can also have an important effect. In large sedimentary basins, numerous driving forces can often influence groundwater movement, resulting in a complex system. Understanding the effects behind groundwater flow, and knowledge of the distribution of different flow regimes are necessary in any groundwater-related scientific or practical problem. Numerical modelling is a useful tool to recognize and distinguish between the different driving forces. In addition, the geological history of the area is a key factor in determining the pressure, temperature and chemical conditions, which have influenced the formation and distribution of flow systems.

The Danube-Tisza Interfluve area, Hungary, was chosen as a study area to investigate the complex effects of various possible driving forces in a porous basin. The area has been very well studied over the past thirty years based on hydraulic data analysis. The presence of a shallow, hydrostatic system and a deep overpressured regime have already been identified. In addition, under favorable geothermal conditions, the effect of temperature cannot be excluded, but its role has not been studied in detail yet. Based on the geological history of the area and applying the groundwater flow system concept, a detailed numerical modelling study was carried out to identify the role of the main driving forces on the groundwater flow regimes. The detailed modelling study suggested that not only gravity, but compression/compaction and density also influence the current flow paths.

The dissemination of the results is supported by the ENeRAG project funded by the European Union's Horizon 2020 research and innovation program under grant agreement No 810980.

Investigation of the Geological and Hydrogeological Conditions in North Tiszántúl Influencing the Efficiency of Geothermal Heat Pump Systems

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Fine-grained sediments are considered to be less favourable than sands or compact rocks regarding geothermal energy extraction with ground source heat pumps. However, the former sediments are significant in the alluvial plains of fluvial environments, especially in areas further away from the provenance area, so an analysis of the conditions for their involvement in heat extraction and storage is well-founded.

Based on numerous strata and logs, geological columns characteristic of geological-geographical units of North Tiszántúl were analysed, including the potential water saturation profile of the unconfined aquifer, based on the typical annual water level fluctuations, the capillarity effect and water loss by gravity. Thermal conductivity of sediment samples was measured under several water saturation conditions with Hukseflux TPSYS02 system and TP08 sensor, so the water saturation profile could be converted to thermal conductivity profile. On the characteristic columns the depth dependence of the annual mean and the fluctuation of spatially averaged thermal conductivity values were calculated in the zone of ground coupled loops (from boreholes to collectors).

Compared to the correlations of sand samples, the fine-grained sediments show only a moderately increasing thermal conductivity with low water content, but near the fully saturated state these sediments have a thermal conductivity (about 2 W/mK) almost like that of the quartz-poor sands. The water saturation of fine-grained sediments usually has smaller annual fluctuations, so the annual mean thermal conductivity may be more favourable than in the case of a sand body characterised by deep groundwater. With usage of the geological columns, the hydrogeological conditions and the obtained correlations, the parameters of the ground coupled loops can be further optimised.

Effects of recharge reduction on the dynamics of complex groundwater flow systems driven by multiple driving forces

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Groundwater reserves, being a crucial water resource, have a great importance in sustainable water management, which requires an effective prediction of future availability. This study aimed at evaluating how groundwater flow systems may alter due to climate change induced recharge reduction in a complex area with two different flow systems and with different fluid driving forces. The Duna-Tisza Interfluve in Hungary was assigned as a pilot area, where two separated flow domains were identified and deeply studied (Mádl-Szőnyi and Tóth, 2009). The upper gravity-driven flow regime is recharged directly from the infiltrating precipitation, while the underlying overpressured flow domain is maintained by pore volume reduction due to compaction and tectonic compression of the basement (Almási 2003; Tóth and Almási, 2001).

Local scale gravity-driven flow systems are the most vulnerable to atmospheric processes, in contrary, overpressured upward flow being non-renewable is expected to be independent of direct climatic variability. In the study special emphasis put on how the relative rate and role of the two fluid flow systems may change due to climate change induced recharge reduction, how the fragmentation of the flow field may alter, how the penetration depth of upper, gravity-driven flow field may adjust to these changes and how groundwater-related shallow surface water bodies will be affected by these changes.

The results of two-dimensional transient numerical groundwater flow simulations helped to evaluate the response of flow systems to the predicted future changes in hydrologic parameters and could provide a base to better mitigate and prepare for its consequences.

The research is supported by the ÚNKP-20-4 New National Excellence Program of the Ministry for Innovation and Technology from the source of the National Research, Development and Innovation Fund, and is part of a project that has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 810980.

Fault-affected fluid circulation revealed by hydrochemistry and isotopes in a large-scale utilized geothermal reservoir

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A new and significant aspect in the utilization of hydrothermal energy in China is large-scale exploitation using multiple wells from a single geothermal site. This requires detailed hydrogeochemical investigations to gain insight about deep groundwater circulation. At the Xiongxian karst geothermal site in northern China, where a demonstration project of large-scale utilization was conducted, 40 boreholes with depths from 1000 to 1800 m were drilled in a region of 50 km^2. A total of 25 water samples were collected and temperature loggings were conducted in 16 of these wells. At the site scale, the hydraulic head was observed to decline from SW to NE, i.e., orthogonal to that at the regional scale. Moreover, the geothermal groundwater temperature, borehole temperature gradient, and heat flow in the caprock all exhibited the same spatial trend with the groundwater head. Based on the hydrogeochemical and temperature logging data, this was explained by mixing of lateral recharging groundwater with ascending thermal fluids through the Xiongxian Fault, after excluding the causes of pumping activities and geologic structure. In addition, geothermal groundwater ^{81}Kr age was estimated to be approximately 760 k yr, which is much older than the ^{14}C age of 20 to 30 k yr. The older ^{81}Kr age implies a low renewability of deep groundwater circulation, which should be considered in terms of sustainable management in relation to the large-scale utilization of geothermal resources.

The true face of Karst thermal groundwater system under the mask of cold-hot water mixing

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Karst geothermal system is one of the most important geothermal types. The particularity of karst media makes geothermal groundwater easier to be influenced by the shallow circulating cold groundwater during its formation, as a result, differs the genetic mechanism of karst geothermal system from others. In present research, the karst geothermal system of Tongluoshan anticline at the margin of Sichuan Basin was taken as an example to reveal the potential misunderstanding of geothermal groundwater genesis caused by the mixing of cold and hot water. A comprehensive approach using of hydrogeochemistry and isotope coupled with field survey were performed to get insight into the mixing process of cold and hot water at the discharge zone of geothermal system. The effects of the mixing on the understanding of geothermal system were deeply discussed. A conceptual model of karst geothermal groundwater system with cold-hot water mixing were established. The results show that the mixing effect of cold and hot water is extremely strong at the discharge zone of geothermal system. The mixing ratio of cold water can be up to more than 70% in the Tongluoshan geothermal system. The mixing of cold and hot water would potentially destroy the information of thermal groundwater for geothermal system, resulting in underestimating the recharge elevation and reservoir temperature. This underestimation reaches to 78% and 45% for recharge elevation and reservoir temperature, respectively, in Tongluoshan geothermal system. The true model of Tongluoshan karst geothermal groundwater system was recognized by eliminating the effects of cold and hot water mixing. The geothermal system is recharged by precipitation in the exposed karst mountain area at an elevation of 2100-2400m in the north. Recharged water is heated by the terrestrial heat flow during its deep circulation. The reservoir temperature of carbonate aquifers of lower Triassic Jialingjiang formation (T_1j) and middle Triassic Leikoupo formation (T_2l) is estimated ranging from 128~172°C. Thermal groundwater is controlled by the karst and geological structure of anticline, and flows from the northeast to the southwest. Thermal water mixes with the local shallow circulating cold water during its discharge. The mixing ratio of cold water reaches to 73~89%. As a result, the temperature of exposed thermal water declines to 38~62°C.

Groundwater hydraulic and age responses to historical climate change in arid and semiarid regions with topographically-driven flow

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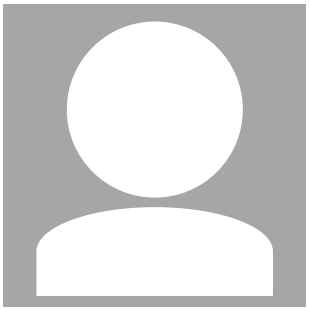
The Pleistocene-Holocene climate transition resulted in a dramatic reduction in groundwater recharge for many aquifers in arid and semiarid regions throughout the world.



This study conducted numerical experiments to compare the evolution of groundwater hydraulics and age patterns in arid and semiarid aquifers in response to extreme conditions with recharge decline to virtually zero in the Holocene. Our results show that after a reduction of recharge the amplitude of the water table undulations reduced as did the regional groundwater slope. This resulted in a general contraction of local flow systems and an increase in the influence of intermediate and regional systems. The previous hierarchy of local, intermediate and regional flow systems were replaced by largely horizontal and regional flow patterns after approximately 10,000 years. However, we observed that the original Pleistocene age patterns remained almost unchanged throughout the Holocene period. Therefore, it is expected that groundwater age is more likely to be indicative of past rather than current flow systems. Consequently, the use of groundwater age to calibrate models or compute recharge with a simple analytical method may lead to misleading results. The finding of this study also applies to areas that have undergone dramatic changes in land cover or land use that strongly influence transient groundwater recharge processes.

Identification of recharge and discharge zones in a gravity-driven regional groundwater flow. The case of the Yucatan Peninsula, Mexico

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The Yucatan Peninsula karst systems are among the most extensive and distinctly shaped landform on the planet. Geological heterogeneities and carbonates deposits carry a historical record of deep heat flow and gravity anomalies, mainly in the Chicxulub impact crater and the transition zones from continental crust to the oceanic basin. According to CONAGUA, INEGI and scientific studies, groundwater in the Yucatan Peninsula constitutes a central source that maintains human activities, environmental processes and groundwater-dependent ecosystems. Local studies on the eastern coast (state of Quintana Roo) have dealt with horizontal cave systems associated with preferential continental groundwater discharge. Further, limited studies have characterized cenotes as surface discharge areas corresponding to uncharacterized flow systems. These previous findings have focused on the epigenetic nature of karst and horizontal flow, underestimating the vertical hydraulic connectivity between geological sequences, the hypogenetic processes and their associated risks and potentials. Recent groundwater investigations have identified regional discharge and recharge areas overall Mexico, including the Yucatan Peninsula, using the Gravity Driven Groundwater Flow Systems (GDGFS) method proposed by Tóth. This study aims to understand the speleogenesis processes based on the GDGFS framework. The main objectives will be defining the epigenetic and hypogenetic nature of karst systems and associated hierarchical flow systems. The investigation will include recharge and discharge regimes in 3D flow patterns within prevailing physicochemical and thermal conditions and natural soil and vegetation covers. Finally, the expected results seek to contribute to the regional characterization and understanding of the spatial distribution of cenotes, sinkholes and springs, and to use these findings as a baseline for adequate future groundwater and environmental management plans in the Yucatan Peninsula.

Aquifer system characterization by passive investigation method

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Effective management of groundwater resources requires accurate estimates of aquifer hydraulic parameters. Traditionally, aquifer test such as pumping test or slug test are commonly used in the field. However, such methods are costly and will cause large disturbance on the aquifer. Furthermore, no time series of hydraulic parameters of the aquifer could be obtained. Here, we proposed to use aquifer water-level responses to natural perturbations, such as barometric pressure and Earth tides. We use time- and frequency-domain methods to estimate aquifer hydraulic properties using these responses to natural perturbations. And we also compared the results obtained from different models and also with traditional aquifer test

Triassic saline fluid flow and epigenetic lead-zinc sulphide mineralization in granite and carbonate basement units along the Transdanubian Shear Zone, Pannonian Basin, Hungary

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Fluid inclusion, K/Ar radiometric age dating and lead-isotope studies on lead-zinc mineralization at two localities situated along the Periadriatic-Balaton Lineament (Transdanubian Shear zone) in the central part of the Pannonian Basin. One of them is hosted by the granite intrusion of Variscan age in the Velence Mts. and the other is hosted by the Paleozoic carbonate rocks at Szabadbattyán. According to the results of fluid inclusion studies, the formation of the quartz-fluorite-galena-sphalerite veins in the Velence Mts is the result of mixing of low salinity sodic (0—12 NaCl equiv. wt. %) and high salinity calcic (10—26 $CaCl_2$ equiv. wt. %) brines. Highly crystalline nature of illite associated with the veins suggesting to hydrothermal origin and about 250 °C maximum temperature. K/Ar radiometric ages of illite are from 209 to 232 Ma, indicating the Mid- to Late-Triassic age of the hydrothermal fluid flow, as such a high temperature later events in the area of veins can be excluded by the results of studies in secondary fluid inclusions in rock forming quartz of the host rock. Fluid inclusion plane studies have revealed that hydrothermal circulation was regional in the granite, but more intensive around the mineralized zones. This is reflected the enhanced number of healed microfractures with fluid inclusions in the zone of veins. The tight clustering of lead isotope signatures of hydrothermal veins in the Velence Mts ($^{206}Pb/^{204}Pb$ = 18.278—18.363, $^{207}Pb/^{204}Pb$ = 15.622—15.690 and $^{208}Pb/^{204}Pb$ = 38.439—38.587) and at Szabadbattyán ($^{206}Pb/^{204}Pb$ = 18.286—18.348, $^{207}Pb/^{204}Pb$ = 15.667—15.736 and $^{208}Pb/^{204}Pb$ = 38.552—38.781) indicate upper crustal source of lead. The nature of mineralizing fluids, age of the fluid flow, as well as the lead isotopic signatures of ore minerals are comparable with the data for epigenetic carbonate-hosted stratiform-stratabound Alpine-type lead-zinc-fluorite deposits in the Southern and Eastern Alps. The large-scale palinspastic tectonic reconstructions suggest, that host rocks of the deposits in the central part of the Pannonian Basin were located in a zone between the Eastern and Southern Alps until the Early Paleogene and were transported to their current location due to the northeastward escape of large crustal blocks from the Alpine collision zone. In spite of the differences in host rocks and the depth of the ore deposition, it is suggested that the studied deposits in the Pannonian Basin and the Alpine-type epigenetic base metal deposits in the Alps belong to the same regional scale fluid flow system, which developed during the advanced stage of the opening of the Neo-Tethys Ocean.

The Effectivity and Potential of Rooftop Rainwater Harvesting by Shallow Well Infiltration in Kerekegyháza, Hungary

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In the Duna-Tisza Interfluve area, groundwater levels have declined significantly in the last decades, due to anthropogenic activities and climate change. The aim of this study is to demonstrate a local scale solution by experimental research in Kerekegyháza, which could contribute to easing the water shortage of the area. Rooftop rainwater harvesting coupled with shallow well infiltration was selected as a method due to its easy and relatively inexpensive implementation and operation. In addition, rainwater is the only adequate source of recharge water at the study area and unused dug wells are readily available.

In the beginning of 2020, a field experiment was set up leading rainwater from the roof of a family house to the dug well in the yard. The water passes through a filter mesh before it enters the tube system leading it to the well. Water level, temperature and specific electrical conductivity is recorded every half hour in the dug well and in two newly established observation wells. Water samples are taken for laboratory measurements. Precipitation is measured on a daily basis. Efficiency was estimated by comparing water level changes after precipitation events with the amount of precipitation falling to the rooftop. Furthermore, long-term water level, hydrochemical and isotopic changes, as well as temperature changes were analyzed to determine the physicochemical effects of injected water on the ambient groundwater. Moreover, a transient numerical flow model was built to understand the occurring underground processes and assess the potential of rooftop rainwater harvesting with different scenarios.

The obtained results can help to understand the effects of rainwater harvesting through shallow well infiltration to follow its effect below the surface, provide background information for further numerical simulations and contribute to expanding the design of similar systems on settlement and regional level in the Duna-Tisza Interfluve.

This research is part of a project that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 810980.

Paleo-flow of basinal fluids in the Transdanubian Range (Western Hungary): fluorite veins at Pécsely

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Fluorite is very common either as major or accessory mineral in a wide variety of ores and may provide information regarding the origin and timing of mineralizing fluid flows. The studied Western Hungarian location is significant, because both the host rock and the studied ore occurrence are geologically connected to the Alps and Alpine-type Pb-Zn deposits, while the described unique phenomenon - H_2 in the vapor phase of fluorite fluid inclusions – is not known elsewhere in the geologically correlated region.

The middle Anisian extensional tectonics of the Neotethyan realm developed a small, isolated carbonate platform in the middle part of the Balaton Highland (W-Hungary), resulted in the deposition of uranium-bearing seamount phosphorite on the top of the drowned platform and produced some epigenetic fluorite veins in the Middle Triassic sequence. The fluorite-dolomite-calcite veins are controlled by normal faults in partly dolomitized limestone. The stable C-O isotope data ($\delta^{18}O_{PDB}$: -6.75 to -5.72‰; $\delta^{13}C_{PDB}$: -7.16 to 2.12‰) of vein-filling carbonates are shifted from the typical Triassic seawater ranges confirming the epigenetic-hydrothermal origin of this mineral paragenesis. Fluorite is characterized by low REE content (15-20 ppm REE+Y). Primary two-phase (L+V) fluid inclusions in fluorite indicate that these veins were formed from low temperature (85-169 °C) and high salinity (15.91 to 22.46 NaCl equivalent weight%) $NaCl+CaCl_2+H_2O$ type hydrothermal fluids. Raman spectroscopic analyses detected H_2 gas in the vapor phase of the fluid inclusions and a defect-rich fluorite structure in violet to black coloured growth zones.

The fluid parameters are similar to fluid inclusion characteristics of saline basinal fluids, which formed the Alpine-type Pb-Zn deposits in the region. These results, together with mineral geochemical data of fluorite prove the existence of the Triassic regional fluid

circulation system also in the Balaton Highland. Based on this study, a new member of the Alpine-type Pb-Zn ore deposits was identified along the Periadriatic-Balaton Lineament in the Alp-Carpathian system. The unique interaction between the fluorite vein forming epigenetic process and the underlying U-containing phosphorite layers as well as the direct stratigraphic relationship of these formations resulted in the presence of hydrogen gas in fluid inclusions, which is possibly related to the in situ (within inclusion) radiolysis of water.

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