DELIVERABLE D8.6
FIRST GEOTHERMAL WEEK SCHOOL ORGANISATION

WP8: COMMUNICATION, DISSEMINATION AND EXPLOITATION

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VF	28/04/2020	-	X. SENGELEN / CYU

CONTENT

1 EXECUTIVE SUMMARY

1.1 DESCRIPTION OF THE DELIVERABLE CONTENT AND PURPOSE

This public deliverable D8.6, entitled "First geothermal week school organisation", has been achieved by CY Cergy Paris Université (CYU) in the framework of the WP8 of the MEET project.

The first geothermal school was organised at CYU in order to allow MEET participants to share their experience obtained during the first 24 months of the project and to learn more about geothermal energy, exploration and production thanks to the invitation of international experts on key topics. In addition, masters and PhD students involved in MEET and other European geothermal projects were invited to participate in this first school to learn and share their first results.

This training programme was organised based on contributions of specialists who contributed with various on-site results, courses and practice-oriented lectures about interdisciplinary geothermal topics.

This deliverable provides all the details of the organisation of the event as planned. The section "Corrective action" is specific to the circumstances of COVID-19 and impact on the geothermal school. Indeed, even if everything was well prepared, the event had to be cancelled due to this specific situation. Eventually, a last part gives perspectives for the second geothermal school that will be held in 2021.

1.2 BRIEF DESCRIPTION OF THE STATE OF THE ART AND THE INNOVATION BREAKTHROUGHS

University or qualifying courses in geothermal energy are very few in Europe and can be very expensive for students. They are either oriented towards the academic sector or focused on technical aspects.

The MEET geothermal school offers a new pedagogical approach by combining both a high quality of teaching and feedbacks from the H2020 MEET European project oriented towards the demonstration of new processes to increase the potential of existing geothermal power plants and to exploit new geothermal reservoirs. All lectures were intended to meet university standards, thanks to the intervention of research and development specialists from the academic and industrial environments, and keynote lectures.

The targeted students are registered in European universities within the MEET project's network of academic partners but also in universities participating in other European deep geothermal projects. This allows an exchange of knowledge within the project, but also between projects of different orientations in order to cover as broadly as possible the research and development on deep geothermal applications.

1.3 CORRECTIVE ACTION

IMPACTS OF COVID-19

Given the high effect of COVID-19 on trans-country mobility, this unexpected sanitary crisis did take a crucial role in decision-making before the event. As mentioned earlier, 18 lecturers, 49 participants and several CYU staff were involved in this event.

1.3.1 Cancellation of MEET Geothermal Spring School 2020: chronology of decisions

Before March the 12th when France decided to close the universities, COVID-19 was not identified as significantly problematic for our event, though CYU staff discussed in depth of the potential scenarios.
At first, recommendations at the country-scale were to restrain events with more than 1000 people (March 9th). With less than 80 people planned at the Geothermal Spring School, the organisation was not at stake, although many students and lecturers already signified that they received restrictions to travel and could not join the physical event. Additionally, exploiting companies of the Melun city contacted CYU one after another to cancel the visits that were planned on March 20th, as did Vermilion partner for the visit of the MEET ORC test-site.
Thus, a general message was sent on March 11th to maintain the event (only the site visits were cancelled), with special dispositions for people restricted at home. In particular, CYU managed to provide a full remote broadcast through ZOOM videoconference. This was still manageable since 10 lecturers guaranteed their presence and more than 30 students could still join.
Then, decision was made to close universities on March 12th. Therefore, CYU could not maintain the physical event at the University, even though public events with less than 100 people could still be maintained (March 13th).
In consequence, it was decided to cancel the Geothermal Spring School 2020 on March 13th. On that Friday preceding the beginning of the training programme (March 13th), CYU notified lecturers and students that the circumstances in France imposed to cancel the Geothermal Spring School 2020.
As it was impossible to organise a videoconference with 80 people in such a short time in cooperation with technicians in distant mode for the next Monday (March 16th, former starting date of the Geothermal Spring School), the virtual event was also cancelled.
This decision was comforted by next announcement on March 16th, when France was declared confined.

1.3.2 Impacts on the project

This unexpected situation is a blow to the dissemination objectives of the MEET project to the academic community, as set out in Task 8.3. Indeed, as the first week of training could not take place, no students enrolled at the Geothermal Spring School 2020 will have access to the results produced during the first period of the project. Therefore, this reduces the visibility at the level of the academic institutions.

1.3.3 Possibilities of mitigating risk of failure

However, the Task 8.3 “Practise oriented education and training” plans the organisation of two geothermal week schools. The impacts can then be lowered by the fact that a second edition of the Geothermal Spring School will be organised at CY Cergy Paris Université (CYU) in March 2021.
The possibility to postpone the event later in 2020 has been eliminated.
The two options were:

- June-July 2020. This period will still be highly impacted by COVID-19;
- Fall 2020. This period is too close to plan again the whole event, given the variable pedagogical programmes of engaged universities and difficulties to

contact freshly registered students early in advance. It is also too close to the Geothermal Spring School 2021.

An optional idea was to organise a sort of MOOC with self-recorded videos of lectures. Hence, it requires a full implication of lecturers while they are currently facing difficulties to provide their usual lectures in their own universities. This possibility will be discussed in the 24M General Assembly in order to study its feasibility.

1.4 IPR ISSUES

N/A

2 DELIVERABLE REPORT

2.1 ORGANISATION OF THE EVENT

2.1.1 1st MEET Geothermal Spring School

The MEET Geothermal Spring School 2020 was planned from the 16th to the 20th of March, 2020 at CY Cergy Paris Université (CYU), in the “Maison Internationale de la Recherche” of the CY Institute of Advanced Studies.

This training programme was articulated around three themes that are common to the MEET project and responding to major issues of the geothermal community, which are:

1. Knowledge of deep geothermal heat & power in various geological settings;
2. Increase heat production, optimization of deep resources in oil wells and existing plants;
3. Promoting EGS across Europe, mapping best locations for future installations in Europe.

18 lecturers from inside and outside MEET consortium were invited to prepare practice-oriented lectures calling to this frame, according to their domain of expertise and their technical experiences. Among these scientists, 4 keynote lectures were planned to give insights on the following general topics:

1. Engineered Geothermal Energy Systems (EGS) in Europe, by Ernst Huenges (GFZ-Potsdam)
2. Deep fractured EGS - Concepts and reservoir assessment in the Upper Rhine Graben, by Albert Genter (ES-Géothermie and Coordinator of MEET project)
3. Social aspects for geothermal energy development and policy implications, by Adele Manzella (Consiglio Nazionale delle Ricerche - Istituto di Geoscienze e Georisorse)
4. IGA Overview - Risk assessment in geothermal: challenging our perception, by Margaret Krieger (IGA)

The audience was made of master (30) and PhD (13) students in majority, as well as one postdoctoral fellow, one junior scientist and a few senior researchers (3).
The participants were targeted in the graduate programmes of the MEET academic partners that are listed below:

- Master programme “GEOSEN” of CY Cergy Paris Université,
- Reservoir engineering programme (4th year) of UniLasalle
- Master programme “Geosciences” of University of Göttingen
- Master of Science “Applied Geosciences” of Technical University of Darmstadt

Wishing to extend the visibility of this training programme and to provide a European platform for students from other geothermal projects, the choice was made to communicate extensively towards students involved in such projects. Consequently, 12 additional students replied to this call.
In total, 49 participants registered to the MEET Geothermal Spring School 2020.

A specific session of presentations for young researchers was planned at the end of each day, in addition to the lectures, allowing students in connection with applied projects, such as MEET or other European geothermal projects, to promote their research work during a 30 minutes talk.
Many students were interested in this initiative and 15 of them submitted an abstract, which was then shared with all students for announcing their presentation.
These presentations were set up to fit the thematic framework of the week and organised according the daily topics.

To end-up the week with a practical experience, one day of site visits was organised in the Melun city, Seine-et-Marne County, southeast of Paris (Figure 1).
Three visits of geothermal heat plants that provision district-heating networks of different generations (early 70’s, 80’s and 2017) were planned with exploiting companies Engie-Réseaux, Dalkia and Idex.
A visit of the MEET test-site of the Organic Rankine Cycle (ORC) device was also set up with Vermilion partner for the demonstration of project-made solutions to enhance geothermal reservoirs.

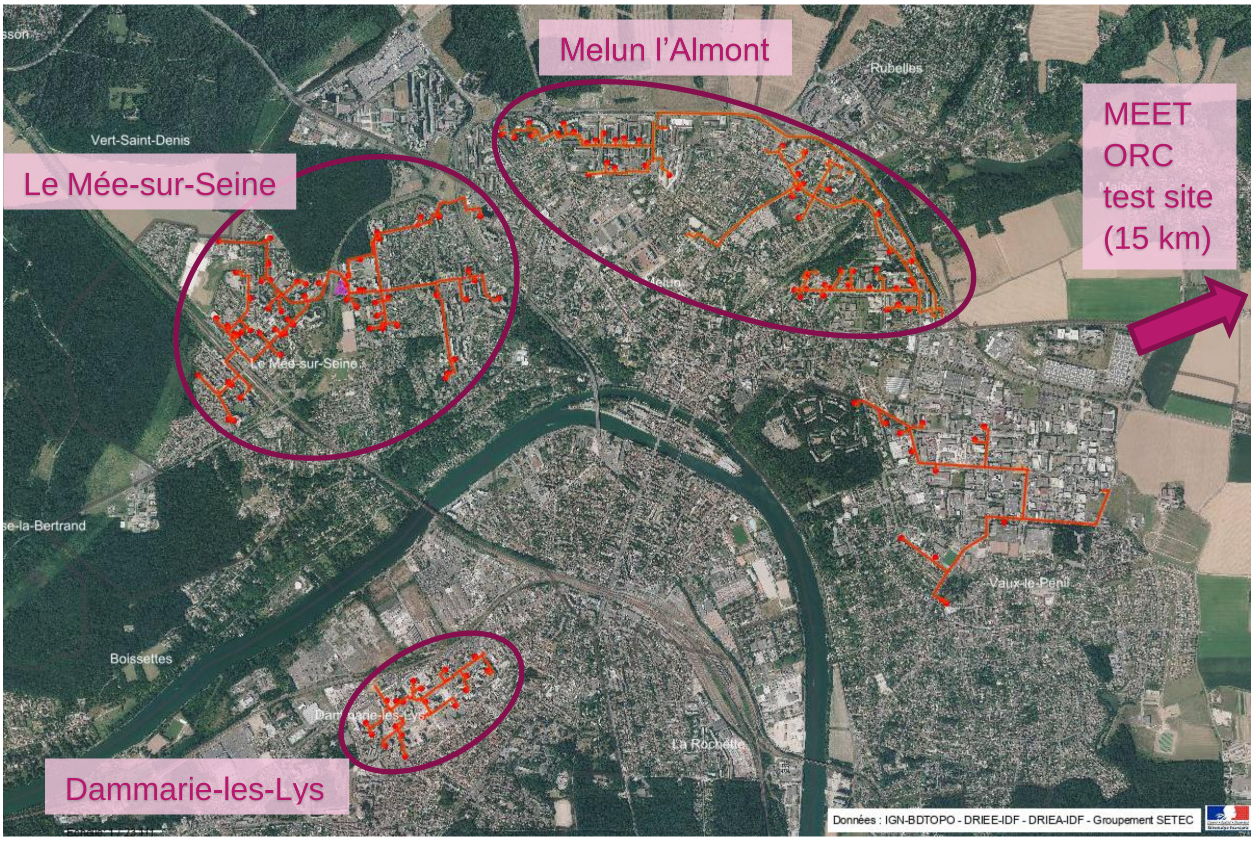


Figure 1: District heating networks of the Melun city, Seine-et-Marne County, southeast of Paris. The visits were planned on the three heating networks provisioned with geothermal energy represented on the map. MEET ORC test site is located 15 km northeast of Melun.

Two groups were constituted to switch between the 4 sites with a shuttle bus during the whole day, with a meeting point at Cergy and returning point in Paris for the end of the week (see the detailed schedule in ANNEX 3: Schedule of the site visits (20th of March, 2020)).

2.1.2 Program

The final program was released three weeks in advance to the participants and lecturers. It is presented below in Figure 2.

Geothermal Spring School 2020

	Monday 03/16	Tuesday 03/17	Wednesday 03/18	Thursday 03/19	Friday 03/20
Thematics	Knowledge of deep geothermal heat & power in various geological settings		Promoting EGS accross Europe: mapping best locations for future installations	Increase heat production: optimization of deep resources in oil well and existing plants	Excursions
8:30 AM	**Introduction & Ice Breaking**				
9:00 AM	**Fabienne Brutin** (Ayming) Boost your researcher career with EU funds	**Kristian Bär** (Technische Universität Darsmstadt) Exploration workflow for deep geothermal systems	KEYNOTE LECTURE **Adele Manzella** (Consiglio Nazionale delle Ricerche - Istituto di Geoscienze e Georisorse) Social aspects for geothermal energy development and policy implications	**Eléonore Dalmais** (ES-Géothermie) Optimization of energy valorization on EGS plant, application to Soultz-sous-Forêts demo-site	
9:30 AM					
10:00 AM					**Geothermal doublets for urban district heating** Melun l'Almont (DALKIA) Le Mée-sur-Seine (IDEX) Dammarie-les-Lys (ENGIE/SOCCRAM)
10:30 AM	KEYNOTE LECTURE **Ernst Huenges** (GFZ) Engineered Geothermal Energy Systems in Europe	**John Reinecker** (Geothermal Engineering GmbH) Planning reservoir stimulation, technical steps and risk mitigation	KEYNOTE LECTURE **Margaret Krieger** (International Geothermal Association) IGA Overview - Risk assessment in geothermal : challenging our perception	**Eric Léoutre** (VERMILION Energy) Oil field conversion to geothermal - surface installations and end-user mapping	
11:00 AM					
11:30 AM					
12:00 PM	**Lunch Break**	**Lunch Break**	**Lunch Break**	**Lunch Break**	
12:30 PM					
1:00 PM	KEYNOTE LECTURE **Albert Genter** (ES-Géothermie) Deep fractured EGS - Concepts and reservoir assessment in the Upper Rhine Graben	**Chaker Raddadi** (VERMILION Energy) Geology of the Paris Basin, Challenges and potential new opportunities for the geothermal sector in the Triassic and Dogger reservoirs.	**Bianca Wagner** (Georg-August Universität Göttingen) Concepts and data sources for mapping deep geothermal resources throughout Europe	**André-Charles Mintsa** (ENOGIA) ORC technology and implementation in different geological contexts	
1:30 PM					
2:00 PM					**Future geothermal power recovery from ORC micro-units** Chaunoy site, Saint-Méry MEET test site (VERMILION Energy)
2:30 PM	**Béatrice Ledésert & Ronan Hébert** (CY Cergy Paris Université) Fractures and hydrothermal alterations: a review of fluid pathways for geothermal applications	**Yves Vanbrabant** (Geological Survey of Belgium) The role of anisotropy in geothermal systems in meta-sedimentary rocks	**Bernd Leiss** (Georg-August Universität Göttingen - Universitätsenergie Göttingen GmbH) An unorthodox exploration and exploitation strategy for the development of an unconventional geothermal reservoir – the Göttingen University campus demo site	**Vincent Lanticq** (FEBUS Optics) Fiber optics, an adaptable and cost-effective technology for monitoring geothermal reservoirs at different scales	
3:00 PM					
3:30 PM	**Ghislain Trullenque** (UniLasalle) Death Valley granites as analogue of EGS Soultz-sous-Forêts reservoir				
4:00 PM		**Ines Raies** - Role of clay minerals in injectivity related to sandstones reservoirs	**Katherine Ford** - Fracture Network Characterization of the Culm Fold Zone (Western Harz Mountains – Germany) as a Means to Extract Geothermal Reservoir Parameters	**Martha Nnko** - Mechanical Characterization and Potential Evaluation of the Geothermal System in Songwe field, Mbeya, Tanzania	
4:30 PM	**Johanne Klee** - Characterization of a geothermal reservoir analogue: Fractured granites of the Noble Hills Range, CA, USA	**Natalia Amanda Vergara** - Joint application of fluid inclusion and clumped isotope (Δ47) thermometry to burial carbonate cements from Upper Triassic reservoirs of the Paris Basin	**Rhadityo Arbarim** - Implementation of hybrid discrete fracture network (DFN) and equivalent porous medium (EPM) approach : an initial step for THM simulation of low temperature injection at the Soultz geothermal project	**Victor Gerald Nzewuji** - System Dynamics Modeling of the Combined Heat Power and Metal extraction (CHPM) concept	
5:00 PM	**Armand Pomart** - Modelling of Fractured Granitic Geothermal Reservoirs: Use of High-Resolution Data in Discrete Fracture Networks and a Coupled Processes Modeling Framework	**Katja Schultz** - analysis of permeability enhancement by chemical treatment in fractured granite (Cornubian Batholithe) for EGS	**Anvar Farkhudtinov** - A numerical modelling approach for geothermal waters sustainable use (the Khankala geothermal field case)	**Máté Osvald** - Laboratory investigations of in situ leaching of tungsten	
5:30 PM	**Baptiste Lepellier** - Characterisation of a fracture-controlled Enhanced Geothermal System (EGS) in the Trans-Mexican-Volcanic-Belt (TMVB)	**Aysegül Turan** - A Coupled THC Modelling Approach Based on Outcrop Analogue Studies and Borehole Data from the Variscan Crystalline Basement in Cornwall (UK): A Case Study for EGS	**Abdelkader Aït Ouali** - Algerian geothermal perspectives by field works studies	**Gemma Mitjanas** - Geophysical investigation of Vallès basin (Spain) and Lazarello geothermal fields (Italy)	
6:00 PM					

Figure 2: Program of the 1st MEET Geothermal Spring School 2020

2.1.3 Student booklet

A student booklet was prepared a week in advance so that every participant could see all the content of the Geothermal Spring School.
It integrates the entire program day by day, with lectures outlines, students' abstracts and contacts, as well as practical details for an adequate personal organisation during the week.
The complete student booklet is attached in ANNEX .

2.1.4 Certificate of participation

A certificate of participation was produced in order to reward the students who participated to the Geothermal Spring School 2020, with the number of days followed by each student. In that way, the document could serve the students who needed to validate some course credits (ECTS) in their own universities, even though this is not an accredited formation neither a proper diploma.
This certificate was co-signed by the President of CY Cergy Paris Université (CYU), François Germinet, and the coordinator of MEET project, Albert Genter (ES-Géothermie).
The preview of the certificate can be found hereafter (Figure 3).

2.1.5 Communication

2.1.5.1 MEET website and LinkedIn page

Publications were released on the MEET website and LinkedIn page on 28th of January, 2020
The specific links are listed below:
- https://www.meet-h2020.com/meet-geothermal-spring-school-2020/
- https://www.linkedin.com/posts/meet-eu-project_meet-geothermal-spring-school-2020-activity-6628334397483429889-tv08/

2.1.5.2 CYU websites

In the same manner, two publications have been released locally on the websites of CY Cergy Paris Université and CY Advanced Studies:
- https://www.u-cergy.fr/fr/recherche-et-valorisation/actualites-recherche/meet-gec-2020.html
- https://iea.u-cergy.fr/en/scientific-events/conferences-and-workshops/geothermal-spring-school-2020.html

2.1.5.3 Posts in the geothermal community

Another way to communicate on the event was to reach the international geothermal community through specialized geothermal news channels. Two of them, ThinkGeoEnergy (IGA) and Global Geothermal news (GRC) wrote an article about the Geothermal Spring School, as listed below:
- https://www.thinkgeoenergy.com/meet-geothermal-spring-school-cy-cergy-paris-university-16-20-march-2020/
- https://geothermalresourcescouncil.blogspot.com/2020/01/france-geothermal_29.html

CERGY PARIS UNIVERSITÉ

MEET Multi-sites EGS Demonstration

CERTIFICATE OF PARTICIPATION

The present document certifies that .... participated during ...... days to the Geothermal Spring School 2020 organized by CY Cergy Paris Université, in the frame of the Horizon 2020 MEET project "Multidisciplinary and multi-context demonstration of EGS exploration and exploitation techniques and potentials".

March 20th, 2020

CY Cergy Paris Université
President
François Germinet

ES-Géothermie
MEET Project Coordinator
Albert Genter

Figure 3: Certificate of participation to the Geothermal Spring School 2020

2.1.5.4 Flyer and poster design

Several visuals were produced to promote the Geothermal Spring School 2020 (see ANNEX 2: Flyer and Poster).

Since autumn 2019, flyers were released for MEET internal diffusion towards students from academic partners. The flyer was also sent to project managers of European geothermal projects.

In winter 2019-2020, posters were designed for internal and external communication on websites and for the event itself. ULS partner as WP8 leader communicated on MEET website and LinkedIn page based on that material (see 2.1.5.1).

2.1.6 Management of the event

2.1.6.1 Exchange with participants, lecturers, and local authorities/energetic operators for site visits

The preparation of the program required many back and forth email exchanges with all lecturers to reconcile personal schedules and thematic framework, but also to collect all lecture outlines needed for the student booklet (see 2.1.3). This effort was made since September 2019 and resulted in a coherent program and a detailed content for students before the start of the Geothermal Spring School. Similarly, many contacts were taken with local authorities of the Melun city, as well as energetic operators in order to plan the site visits in close cooperation leading to a schedule to get to each of the 4 industrial sites by bus (see ANNEX 3: Schedule of the site visits (20th of March, 2020)).

2.1.6.2 Funding proposals

While the organisation of the first Geothermal Spring School required a significant budget to handle logistical costs, the grant received by CYU for the MEET project did not include a dedicated support for the WP8 - Task 8.3. Consequently, CYU had to answer several calls for funding of the Geothermal Spring School 2020, both inside and outside the university.

Proposals were sent to three different organisms that could provide grants for our project:

1. CY Advanced Studies – Organisation of Scientific Manifestation
2. International Geothermal Association (IGA)
3. UCP Foundation

From these proposals, two of them received a satisfactory answer (1. and 2.) and allowed CYU to obtain equity for covering all planned costs.

Both organisms asked to associate their logos on communication materials prepared for the event. The program, posters and student booklet were stamped with CY Advanced Studies and IGA logos alongside MEET logo.

2.1.6.3 Catering and accommodation

In order to welcome guests, lecturers and participants in proper conditions, a catering was organised and included a welcome buffet on Monday 16th of March, as well as daily lunch for all lecturers. The local student restaurant (CROUS) was warned of the raising of the demand with 50 additional lunches for the students registered to the Geothermal Spring School.

The lecturers who travelled long trips from abroad and far distance from France were proposed to stay overnight in the International Researchers Guesthouse, right next to the "Maison Internationale de la Recherche", so that they had an adequate access to the

auditorium before or after staying overnight. This solution was set long in advance since the guesthouse is usually preferred for invited researchers of the whole university.
A total of 13 lecturers chose this option and flats were ready for them on the week before the event.
Similarly, CYU exchanged intensively with students, with active targeting of participants among European geothermal projects and MEET academic partners. Few months before the event, a proposition was made for students who wanted to show their work during a 30-minutes oral presentation in the so-called “session for young researchers”. In order to properly organise this session, the interested students had to send their abstract on a voluntary-basis with a title that was then integrated in the final program. All the abstracts can be found in the “Student booklet” (see 2.1.3 and ANNEX).

2.1.6.4 Logistics of the venue

To make sure the event could be held satisfactorily, the auditorium was booked a year ahead, and the lecture rooms several months before. Together with full flats of the International Researchers Guesthouse, almost the whole building was prepared and booked for the event.
In addition, logistical material was prepared a week before the event in order to ensure fluidity in the reception of participants and guest lecturers. Badges, lists, group identifiers for the Icebreaker were ready on time, as well as poster printing and beverages.

2.2 PERSPECTIVES FOR THE NEXT EDITION

2.2.1 Capitalization

The Geothermal Spring School 2021 will most certainly consist in a very close format to what was planned in 2020. Therefore, all contacts will be reactivated during the course of the year 2020 in order to propose an attractive program for Master and PhD students. Some lecturers already consider re-scheduling their training course or keynote lecture cancelled due to the COVID-19 pandemia for the next edition. It will guarantee a successful event that will provide efficient dissemination towards the academic community in geothermal research and development.

2.2.2 Co-organisation with the European Geothermal PhD Days 2021

The future perspectives for a fruitful event are strengthened since CYU application to the organisation of the **European Geothermal PhD Days (EGPD) 2021**, in collaboration with Université de Neufchâtel (UNINE), was accepted on February the 26th by the organizing committee of the EGPD 2020 in Turkey, as indicated in the following message received on February the 28th:

"*Dear Distinguished Members of University of Cergy,*
As the organizing committee of EGPD 2020, we are happy to inform you that you have been selected as the next host institution of European Geothermal PhD Day 2021.
We have received your letter of intent and that letter was read aloud to the all participants at the congress dinner.
Since it was the only letter stating the motivation of being next host university, it was accepted with no voting process.
It has been welcomed as it will be the first time of France and combined with Geothermal Spring School by increasing the benefits of participating for a PhD candidate.
We would like to inform you that we will be ready for sharing our experience when you need.
We wish you a successful event in advance.

Dr. Taylan AKIN
On behalf of organising committee"

The EGPD gathers about 50 to 80 PhD students each year since 2009 and intends to "connect PhD researchers all over Europe that are working in the field of geothermal energy". These young scientists are working on many different research fields such as geology, geochemistry, rock mechanics, geophysics and mechanical engineering.
Traditionally, guest lecturers give oral presentations and PhD students are asked to submit an abstract to present their projects in poster sessions during the conference.

The EGPD has been hosted in many European countries in the past decade, but it is the first time it will be organised in France.
As the organising committee has to be composed of PhD students in geothermal and CYU does currently host 1 part-time PhD candidate in this domain, CYU associated with Université de Neufchâtel whose PhD candidates accepted to co-organise the event. The

Center for Hydrogeology and Geothermics, and more specifically the Geothermics and Reservoir Geomechanics laboratory will be the privileged contacts for preparing the EGPD 2021. PhD students from UNINE (Neuchâtel) will be in charge of organizing work sessions based on the abstracts received. CYU will organize the logistic part of the event (booking of Institute for Advanced Studies for the auditorium and lecture rooms as well as accommodation for the keynote lecturers, organisation of the visit tour, of the dinner, etc).

This jointly event of MEET Geothermal Spring School 2021 and European Geothermal PhD Days 2021 that will be held at the “Maison Internationale de la Recherche” of CY Cergy Paris Université in March 2021 represents a unique chance for PhD students to follow a week of intense knowledge sharing and promotion. Indeed, students will have the opportunity to follow keynote lectures, conferences, practice-oriented courses, poster sessions, young researcher presentations and a day of site visits that will be common to both events.

In terms of training and dissemination of MEET activities, these perspectives are very encouraging for a success of Task 8.3 “Practice oriented education and training”, especially after the outbreak of COVID-19 that disorganised a significant effort to achieve the first part of this task.

The annexes below provide student booklet (ANNEX 1: Student booklet) as well as poster and flyer made for the announcement of the 2020 Geothermal Spring School on social networks (ANNEX 2: Flyer and Poster) and program of the site visits planned for the 20th of March 2020 (ANNEX 3: Schedule of the site visits (20th of March, 2020)).

ANNEX 1: STUDENT BOOKLET

Geothermal Spring School 2020

16-20th March 2020

CY Cergy Paris Université

Neuville campus

Maison Internationale de la Recherche

MEET Multi-sites EGS Demonstration | CY CERGY PARIS UNIVERSITÉ | CY ADVANCED STUDIES | IGA INTERNATIONAL GEOTHERMAL ASSOCIATION

Geothermal Spring School 2020

	Monday 03/16	Tuesday 03/17	Wednesday 03/18	Thursday 03/19	Friday 03/20
Thematics	**Knowledge of deep geothermal heat & power in various geological settings**		**Promoting EGS accross Europe: mapping best locations for future installations**	**Increase heat production: optimization of deep resources in oil well and existing plants**	**Excursions (cancelled)**
8:30 AM	**Introduction & Ice Breaking**				**Geothermal doublets for urban district heating** Melun l'Almont (DALKIA) Le Mée-sur-Seine (IDEX) Dammarie-les-Lys (ENGIE/SOCCRAM)
9:00 AM	**Fabienne Brutin** **(Ayming)** Boost your researcher career with EU funds	**Kristian Bär** **(Technische Universität Darsmstadt)** Exploration workflow for deep geothermal systems	KEYNOTE LECTURE **Adele Manzella** **(Consiglio Nazionale delle Ricerche - Istituto di Geoscienze e Georisorse)** Social aspects for geothermal energy development and policy implications	**Eléonore Dalmais** **(ES-Géothermie)** Optimization of energy valorization on EGS plant, application to Soultz-sous-Forêts demo-site	
9:30 AM					
10:00 AM					
10:30 AM	KEYNOTE LECTURE **Ernst Huenges** **(GFZ)** Engineered Geothermal Energy Systems in Europe	**John Reinecker** **(Geothermal Engineering GmbH)** Planning reservoir stimulation, technical steps and risk mitigation	KEYNOTE LECTURE **Margaret Krieger** **(International Geothermal Association)** IGA Overview - Risk assessment in geothermal : challenging our perception	**Eric Léoutre** **(VERMILION Energy)** Co-production of oil and geothermal heat: opportunities and challenges	
11:00 AM					
11:30 AM					
12:00 PM	Lunch Break	Lunch Break	Lunch Break	Lunch Break	
12:30 PM					
1:00 PM	KEYNOTE LECTURE **Albert Genter** **(ES-Géothermie)** Deep fractured EGS - Concepts and reservoir assessment in the Upper Rhine Graben	**Chaker Raddadi** **(VERMILION Energy)** Geology of the Paris Basin, Challenges and potential new opportunities for the geothermal sector in the Triassic and Dogger reservoirs.	**Bianca Wagner** **(Georg-August Universität Göttingen)** Concepts and data sources for mapping deep geothermal resources throughout Europe	**André-Charles Mintsa** **(ENOGIA)** ORC technology and implementation in different geological contexts	**Future geothermal power recovery from ORC micro-units** Chaunoy site, Saint-Méry MEET test site (VERMILION Energy)
1:30 PM					
2:00 PM					
2:30 PM	**Béatrice Ledésert & Ronan Hébert** **(CY Cergy Paris Université)** Fractures and hydrothermal alterations: a review of fluid pathways for geothermal applications	**Yves Vanbrabant** **(Geological Survey of Belgium)** The role of anisotropy in geothermal systems in meta-sedimentary rocks	**Bernd Leiss** **(Georg-August Universität Göttingen - Universitätsenergie Göttingen GmbH)** An unorthodox exploration and exploitation strategy for the development of an unconventional geothermal reservoir – the Göttingen University campus demo site	**Vincent Lanticq** **(FEBUS Optics)** Fiber optics, an adaptable and cost-effective technology for monitoring geothermal reservoirs at different scales	
3:00 PM					
3:30 PM	**Ghislain Trullenque** **(UniLasalle)** Death Valley granites as analogue of EGS Soultz-sous-Forêts reservoir				
4:00 PM		**Ines Raies** - Role of clay minerals in injectivity related to sandstones reservoirs	**Katherine Ford** - Fracture Network Characterization of the Culm Fold Zone (Western Harz Mountains – Germany) as a Means to Extract Geothermal Reservoir Parameters	**Martha Nnko** - Mechanical Characterization and Potential Evaluation of the Geothermal System in Songwe field, Mbeya, Tanzania	
4:30 PM	**Johanne Klee** - Characterization of a geothermal reservoir analogue: Fractured granites of the Noble Hills Range, CA, USA	**Natalia Amanda Vergara** - Joint application of fluid inclusion and clumped isotope (Δ47) thermometry to burial carbonate cements from Upper Triassic reservoirs of the Paris Basin	**Rhadityo Arbarim** - Implementation of hybrid discrete fracture network (DFN) and equivalent porous medium (EPM) approach : an initial step for THM simulation of low temperature injection at the Soultz geothermal project	**Victor Gerald Nzewuji** - System Dynamics Modeling of the Combined Heat Power and Metal extraction (CHPM) concept	
5:00 PM	**Armand Pomart** - Modelling of Fractured Granitic Geothermal Reservoirs: Use of High-Resolution Data in Discrete Fracture Networks and a Coupled Processes Modeling Framework	**Katja Schultz** - analysis of permeability enhancement by chemical treatment in fractured granite (Cornubian Batholithe) for EGS	**Anvar Farkhudtinov** - A numerical modelling approach for geothermal waters sustainable use (the Khankala geothermal field case)	**Máté Osvald** - Laboratory investigations of in situ leaching of tungsten	
5:30 PM	**Baptiste Lepellier** - Characterisation of a fracture-controlled Enhanced Geothermal System (EGS) in the Trans-Mexican-Volcanic-Belt (TMVB)	**Aysegül Turan** - A Coupled THC Modelling Approach Based on Outcrop Analogue Studies and Borehole Data from the Variscan Crystalline Basement in Cornwall (UK): A Case Study for EGS	**Abdelkader Aït Ouali** - Algerian geothermal perspectives by field works studies	**Gemma Mitjanas** - Geophysical investigation of Vallès basin (Spain) and Lazarello geothermal fields (Italy)	
6:00 PM					

Geothermal Spring School 2020

Meeting Date: 16-20th March 2020

Meeting Venue: Maison Internationale de la Recherche - CY Cergy Paris Université

Contact Person N°1: Xavier Sengelen Mobil phone : +33 6 84 84 62 55
Contact Person N°2: Béatrice Ledésert Mobil phone : +33 6 71 63 30 44

Geothermal Spring School 2020			
DAY 1 - 16/03/2020			
Agenda Item	**Speaker**	**Starting Time**	**Duration**
Meeting starting time		**08:00**	
Welcome coffee		08:00	00:20
Safety instructions and Introduction by host partner	Xavier Sengelen (CYU)	08:20	00:10
Ice breaker	Fabienne Brutin (AYMING)	08:30	00:30
Boost your research career with EU funds	Fabienne Brutin (AYMING)	09:00	01:25
Coffee Break		**10:25**	**00:10**
KEYNOTE LECTURE : Engineered Geothermal Energy Systems in Europe	Ernst Huenges (GFZ)	10:35	01:25
Lunch		**12:00**	**01:00**
KEYNOTE LECTURE : Deep fractured EGS - Concepts and reservoir assessment in the Upper Rhine Graben	Albert Genter (ES-Géothermie)	13:00	01:25
Fractures and hydrothermal alterations: a review of fluid pathways for geothermal applications	Béatrice Ledésert and Ronan Hébert (CYU)	14:25	00:55
Coffee Break		**15:20**	**00:15**
Death Valley granites as analogue of EGS Soultz-sous-Forêts reservoir	Ghislain Trullenque (UniLasalle)	15:35	00:55
Characterization of a geothermal reservoir analogue: Fractured granites of the Noble Hills Range, CA, USA	Johanne Klee (UniLasalle)	16:30	00:30
Modelling of Fractured Granitic Geothermal Reservoirs: Use of High-Resolution Data in Discrete Fracture Networks and a Coupled Processes Modeling Framework	Armand Pomart (UniLasalle)	17:00	00:30
Characterisation of a fracture-controlled Enhanced Geothermal System (EGS) in the Trans-Mexican-Volcanic-Belt (TMVB)	Baptiste Lepillier (TUDelft)	17:30	00:30
Conclusion day 1	Xavier Sengelen (CYU)	18:00	00:05
Meeting closed		**18:05**	

Geothermal Spring School 2020			
DAY 2 - 17/03/2020			
Agenda Item	**Speaker**	**Starting Time**	**Duration**
Meeting starting time		**09:00**	
Exploration workflow for deep geothermal systems	Kristian Bär (TUDarmstadt)	09:00	01:25
Coffee Break		**10:25**	**00:10**
Planning reservoir stimulation, technical steps and risk mitigation	John Reinecker (GeoThermal Engineering)	10:35	01:25
Lunch		**12:00**	**01:00**
Geology of the Paris Basin, Challenges and potential new opportunities for the geothermal sector in the Triassic and Dogger reservoirs.	Chaker Raddadi (Vermilion)	13:00	01:25
The role of anisotropy in geothermal systems in meta-sedimentary rocks	Yves Vanbrabant (Geol. Survey of Belgium)	14:25	01:25
Coffee Break		**15:50**	**00:10**
Role of clay minerals in injectivity related to sandstones reservoirs	Ines Raies (CYU / IFPEN)	16:00	00:30
Joint application of fluid inclusion and clumped isotope (Δ47) thermometry to burial carbonate cements from Upper Triassic reservoirs of the Paris Basin	Natalia Amanda Vergara (U. Roma Tre / IFPEN)	16:30	00:30
Analysis of permeability enhancement by chemical treatment in fractured granite (Cornubian Batholithe) for EGS	Katja Schultz (TUDarmstadt)	17:00	00:30
A Coupled THC Modelling Approach Based on Outcrop Analogue Studies and Borehole Data from the Variscan Crystalline Basement in Cornwall (UK): A Case Study for EGS	Aysegül Turan (TUDarmstadt)	17:30	00:30
Conclusion day 2	Xavier Sengelen, CYU	18:00	00:05
Meeting closed		**18:05**	

Geothermal Spring School 2020			
DAY 3 - 18/03/2020			
Agenda Item	**Speaker**	**Starting Time**	**Duration**
Meeting starting time		09:00	
KEYNOTE LECTURE : Social aspects for geothermal energy development and policy implications	Adele Manzella (CNR)	09:00	01:25
Coffee Break		**10:25**	**00:10**
KEYNOTE LECTURE : IGA Overview - Risk assessment in geothermal : challenging our perception	Margaret Krieger (IGA)	10:35	01:25
Lunch		**12:00**	**01:00**
Concepts and data sources for mapping deep geothermal resources throughout Europe	Bianca Wagner (Universität Göttingen)	13:00	01:25
An unorthodox exploration and exploitation strategy for the development of an unconventional geothermal reservoir – the Göttingen University campus demo site	Bernd Leiss (Universität Göttingen)	14:25	01:25
Coffee Break		**15:50**	**00:10**
Fracture Network Characterization of the Culm Fold Zone (Western Harz Mountains – Germany) as a Means to Extract Geothermal Reservoir Parameters	Katherine Ford (Universität Göttingen)	16:00	00:30
Implementation of hybrid discrete fracture network (DFN) and equivalent porous medium (EPM) approach : an initial step for THM simulation of low temperature injection at the Soultz geothermal project	Rhadityo Arbarim (Universität Göttingen)	16:30	00:30
A numerical modelling approach for geothermal waters sustainable use (the Khankala geothermal field case)	Anvar Farkhudtinov (Bashkir State University)	17:00	00:30
Algerian geothermal perspectives by field works studies	Abdelkader Aït Ouali (CDER)	17:30	00:30
Conclusion day 3	Xavier Sengelen, CYU	18:00	00:05
Meeting closed		18:05	

Geothermal Spring School 2020			
DAY 4 - 19/03/2020			
Agenda Item	**Speaker**	**Starting Time**	**Duration**
Meeting starting time		09:00	
Optimization of energy valorization on EGS plant, application to Soultz-sous-Forêts demo-site	Eléonore Dalmais (ES-Géothermie)	09:00	01:25
Coffee Break		**10:25**	**00:10**
Co-production of oil and geothermal heat: opportunities and challenges	Eric Léoutre (Vermilion)	10:35	01:25
Lunch		**12:00**	**01:00**
ORC technology and implementation in different geological contexts	André-Charles Mintsa (Enogia)	13:00	01:25
Fiber optics, an adaptable and cost-effective technology for monitoring geothermal reservoirs at different scales	Vincent Lanticq (Febus Optics)	14:25	01:25
Coffee Break		**15:50**	**00:10**
Mechanical Characterization and Potential Evaluation of the Geothermal System in Songwe field, Mbeya, Tanzania	Martha Nnko (TUDelft)	16:00	00:30
System Dynamics Modeling of the Combined Heat Power and Metal extraction (CHPM) concept	Victor Gerald Nzewuji (University of Miskolc)	16:30	00:30
Evaluation of Granites in Gilgit-Baltistan (Pakistan) as Potential Geothermal Prospects	Muhammad Anees (Universität Göttingen)	17:00	00:30
Geophysical investigation of Vallès basin (Spain) and Lazarello geothermal fields (Italy)	Gemma Mitjanas (Universitat de Barcelona)	17:30	00:30
Conclusion of Geothermal Spring School 2020	Xavier Sengelen, CYU	18:00	00:15
Meeting closed		18:15	

Practical information

Coronavirus Covid-19

Due to the global sanitary situation, all participants on site should respect security requirements, which consist in washing hands as often as possible, not shaking hands, sneezing in their arms and using paper tissues.

Videoconference

Regarding the impossibility for many people to join CY Cergy Paris Université, we have set up a **remote broadcasting of the event**, which will allow full exchange between all lecturers and students. **Everyone must have its presentation ready for the scheduled time slot** (see above program).
The **ZOOM application** will be used to follow from distance, share presentations, ask questions, see all the participants (presenters and students in the auditorium, and presenters and students in distant mode). It is stable, efficient and will allow full exchange between lecturers and students.
Please install the ZOOM executable file send by e-mail before the start of the Spring School, so that you can join us as soon as the first speaker starts.
We will send the links to join the videoconference on each day to all people that announced they are restricted to come.
These links will be active for one day each, so you will need to activate them on the beginning of each day.

Access to the Neuville campus of CY Cergy Paris Université

MAISON INTERNATIONALE DE LA RECHERCHE - CY Cergy Paris Université
1, rue Descartes 95000 Neuville-surOise
Phone : 01 34 25 64 30 // 07 63 94 81 08

By car

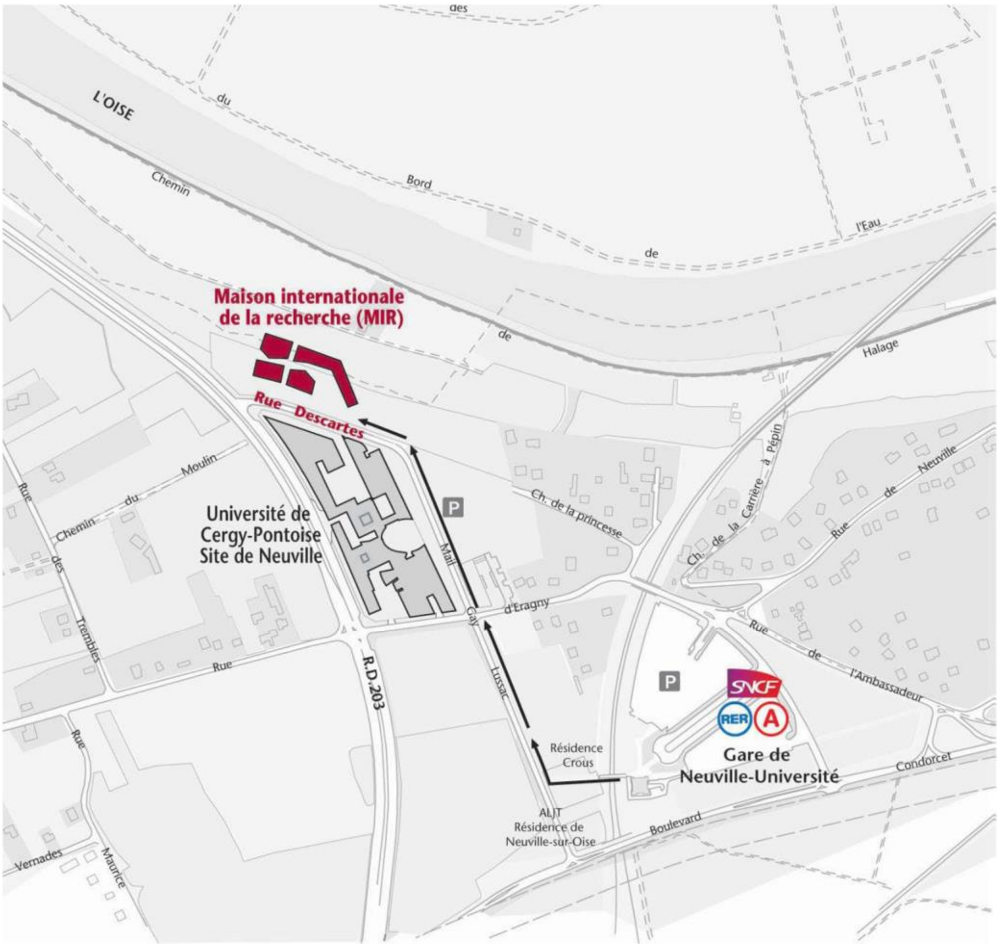
>From Paris: from Porte Maillot, direction La Défense. Take the A86 then the A15, following signs for Cergy-Pontoise, and come off at exit(sortie) 7. Take the N184 towards Versailles/Jouy-le- Moutier/Neuville-sur-Oise.
>From Versailles: Take the N184 towardsBeauvais until Conflans-Sainte-Honorine, thenfollow Neuville-sur-Oise.
GPS coordinates: 49.018246, 2.073883

By RER line A

Take RER line A (terminus: Cergy-Le-Haut) to Neuville-Université; "Côté Université" exit.

By train

From Paris Saint-Lazare, take line L (terminus: Cergy-Le-Haut) to Neuville-Université; "Côté Université" exit



Certificate of participation

All students will be given a certificate of participation of the Geothermal Spring School 2020 at the end of the week, with the number of days of presence that could be valorised to apply for ECTS equivalent in universities, when possible.
For students who will follow from distance through ZOOM, we will register you everyday 30 min before the start of the day and also at the end of the day.

MEET Geothermal Spring School 2021

We announce you that the second edition of the Geothermal Spring School will be held next year in March 2021.
It will be organized jointly with the 2021 edition of the European Geothermal PhD Days, during the same week, in partnership between CY Cergy Paris Université (CYU) and Université de Neufchâtel (UNINE).
We hope to see you again, as well as many PhD students from all over Europe.

List of attendees (students/fellows)

See at the end of the booklet (p.43)

Detailed Program

Monday 16th

Knowledge of deep geothermal heat & power in various geological settings

Introduction

Icebreaker

Fabienne Brutin (Ayming)
Boost your research career with EU funds

Nowadays, no researcher, whatever in public or private organisations, can ignore or even underestimate the mechanisms and power of public funding, especially at European Union level. European Commission, through the Framework Programme for Research, Development and Innovation, supports the EU research through various so-called "funding instruments" according to its social, economic and competiveness needs.

Keynote lecture:
Ernst Huenges (GFZ Potsdam)
Engineered Geothermal Energy Systems in Europe

- Introduction with some motivation for geothermal energy (heat or electricity) provision,
- European targets, with some potential maps and rough exploration strategies
- Reservoir characterisation, i.e. relevant rock and fluid properties, stress, permeability, and temperature and fundamental equations
- Reservoir engineering, i.e. soft stimulation approaches and testing
- Geothermal fluid loops and utilisation and
- Conclusions

Keynote lecture:

Albert Genter (Scientific Director of ES-Géothermie and MEET project coordinator)

Deep fractured EGS, concepts and reservoir assessment in the Upper Rhine Graben

The Upper Rhine Graben (URG) was historically the root for the development of a new type of deep geothermal energy aiming to exploit the heat extracted from crystalline rocks hidden by a thick sedimentary cover.
Based on deep drillings penetrating the crystalline basement of the URG at Soultz-sous-Forêts (Alsace, France), various geothermal concepts like Hot Dry Rock, Hot Fractured Rocks, Hot Wet Rock, and a more recent approach was defined by the geothermal community as EGS, Enhanced Geothermal Systems or Engineered Geothermal Systems. EGS is more a technology than a concrete geothermal concept aiming to enhancing a low permeable well for reaching an economic threshold by applying thermo-hydro-chemical treatments.
Based on existing geothermal sites operating in the Upper Rhine Graben, this presentation will illustrate how EGS technology is still on the learning curve and could produce electricity and heat from deep fractured basements.

Béatrice Ledésert and Ronan Hébert (CY Cergy Paris Université)

Fractures and hydrothermal alterations: a review of fluid pathways for geothermal applications

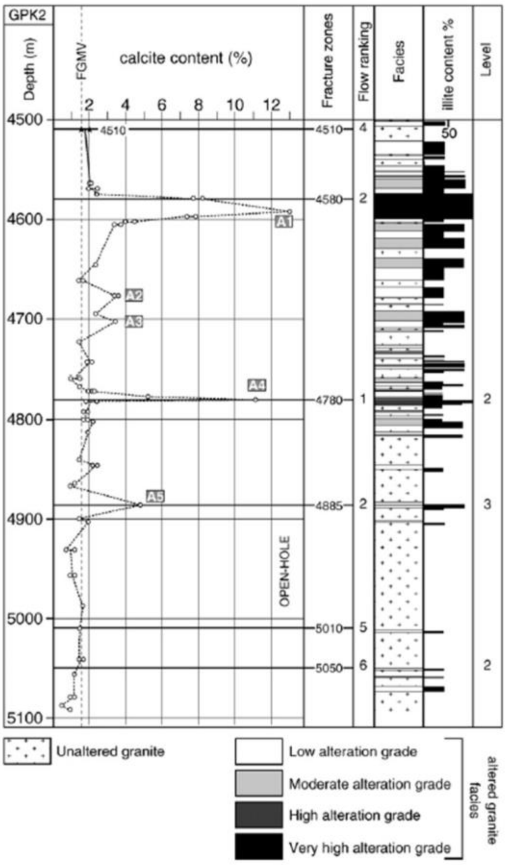
In order to better know the pathways followed by the fluids in geothermal reservoirs, one has to look for clues. Among them, discontinuities, porosity and hydrothermal alteration have proven to be very efficient.
Discontinuities in general (fractures, faults, joints between debris flows or lava flows in volcanic settings, unconformities, grain joints at a smaller scale) as well as connected porosity (created by dissolution of primary minerals for example) are prone to fluid flow because of the voids they constitute.
When a natural hot fluid circulates in those voids, it interacts with the rock and modifies it creating the so-called hydrothermal alteration. This alteration is responsible for the modification of the structure (increase of porosity, decrease of density), of the chemistry of the rock (loss or gain of chemical elements) and of the precipitation of newly formed phases in porosity (dissolution of primary minerals followed by precipitation of newly formed phases) and in discontinuities (fracture infilling, sealing of discontinuities).
The exploration of geothermal reservoirs is performed first in the field (geophysics, geological mapping, and structural geology). The second step occurs in drillings, when available, to look for discontinuities either on cores or on well logs (e.g. borehole imaging) and to study the nature of the rock (possible also if only rock-chips are produced by destructive drilling) including mineralogy of primary and secondary (newly formed) phases.

This talk is divided in two parts:

1- Characterization of discontinuities

2- Description and interpretation of hydrothermal alteration.

The figure below illustrates this approach in the deep reservoir at Soultz-sous-Forêts (Upper Rhine Graben, borehole GPK-2).
In Hébert et al. (2010) The Enhanced Geothermal System of Soultz-sous-Forêts: A study of the relationships between fracture zones and calcite content, Journal of Volcanology and Geothermal Research.



Calcite content (star: new data; circle: data from Ledésert et al., 2009), fracture zones (from Gentier et al., 2005; Sausse et al., 2007), flow ranking (from Sausse et al., 2007), petrographic facies and illite content (from Genter et al., 1999) vs. depth (m MD). FGMV dashed line corresponds to the fresh granite maximum value of calcite (1.8 %, White et al., 2005). A1 to A5 are calcite anomalies defined by Ledésert et al. (2009). Fracture zones in the Soultz wells are classified within three levels according to their importance as fluid flow paths (level 1= the highest).

In GPK2, the fracture zones with the best fluid flow correlate with the highest calcite anomalies, whereas the less conductive do not show abnormal calcite content.

Ghislain Trullenque (UniLaSalle – MEET scientific coordinator)

The concept of geothermal reservoir analogue: a case study at the Noble hills range, southern Death Valley, CA, USA

Geothermal reservoir exploration and exploitation are challenging tasks given the extraordinary variety of parameters and uncertainties to be taken into account.
One of the main reasons for these challenges are to be found in the lack of geological data directly available in the field as the reservoirs are usually buried at depths greater than a 1000 meters. Geological knowledge can therefore only be gained using a limited amount of borehole data and geophysical investigations which in turn forces the engineers to sometimes oversimplify their simulations.
In the present note, we are going to present a way to circumvent these limitations by performing highly detailed geological studies on naturally exhumed geothermal reservoirs. We will first discuss the validity of the approach by defining the concept of a reservoir analogue. We will show that the point is not to find a perfect replication of a given potential exploitation site. We believe that the analogue is an object to be used in order to study at large scale with the maximum precision a given process or a combination of processes of primary importance in the gain of geothermal energy.
The MEET project includes a variety of analogues and these will be summarized with a special focus on an analogue to the Soultz sous Forêts (SsF) demonstration site situated in the Rhine grabben, Alsace, France.
The chosen analogue is found at the southern termination of the Southern Death Valley National park, in the Noble Hills (NH), CA, USA. This range has suffered vast amounts of right lateral deformation as presented by Pavlis and Trullenque (Subm.). In spite of the distancing between SsF and NH areas a summary of the work performed by Klee et al 2020 will show several key geological similarities in terms of rock nature, tectonic regime and fluid circulation record. These findings lead to consider the chosen analogue as valuable for a range of reservoir key parameters. A striking analogy between the NH range and the SsF reservoir in terms of fluid rock interaction processes, deformation mechanisms and rock fracture processes are indeed observed.
The different analogies will be presented and explained using raw field data in order to convince the audience about the validity of the approach.
These data are planned to be used in the near future for reservoir exploitation simulations and this approach started by Trullenque et al. 2020 will then be introduced.

Young researcher:

JOHANNE KLEE (PHD STUDENT AT UNILASALLE - FRANCE)

Characterization of a geothermal reservoir analogue: Fractured granites of the Noble Hills Range, CA, USA

The work presented here is part of the European MEET project (Multidisciplinary and multi-context demonstration of EGS exploration and Exploitation Techniques and potentials), which aims to enhance demonstration of geothermal energy production throughout Europe. We present a preliminary geothermal reservoir model from a fractured and altered granitic body found in the Noble Hills (NH, Southern Death Valley, CA, USA) chosen as an analogue model of the Soultz-sousForêts (SsF) geothermal reservoir (Upper Rhine Graben, Alsace, France). Analogue work includes a robust petrographical and petrophysical analyzes of encountered rocks combined to a precise photogrammetric study based on reconstruction of fracture network. Our current state of knowledge reveals that the NH reservoir is composed of one Mesozoic granite which can be ultracataclastic but also more competent, albeit heavily fractured. The composition of the granite and its alteration processes present obvious similarities with the ones at SsF: oligoclase and biotite are respectively transformed into kaolinite (tosudite at SsF)/ illite/calcite and illite.

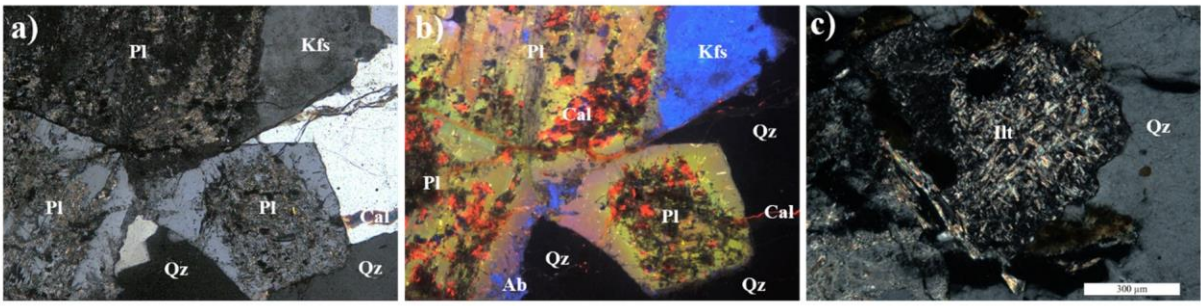


Fig 1: Images a) of altered plagioclases under optical microscope in polarized and analyzed light, b) of the same plagioclases than a) under cathodoluminescence presenting the calcite in red, in pink-green the plagioclases with a blueish albite rim and also in blue the K-feldspars and c) of an altered plagioclase with illite precipitation under optical microscope in polarized and analyzed light

Moreover, fractures contains different infills (carbonates, oxides, barite and sometimes quartz) which can result in different fluid generations. By combining analogues studies and microstructural inspection of SsF core type samples we aim at 1) better understand fluid circulations in the granitic fractured reservoirs and 2) gain insights in fluid rock interaction processes as these can drastically modify fractures properties through time. Structural investigations of the SsF cores shows that more than 90% of the fractures are completely sealed. Reservoir productivity is indeed only taken up by a few opened fractures showing incipient geodic quartz precipitations. Interestingly such opened fractures or even undeformed quartz veins are rarely observed in our reservoir analogues. Far away more common in both NH analogues and SsF cores are the occurrences of 1) relicts from quartz veins reworked by incipient cataclastic deformation processes leading to vein brecciation and 2) ultracataclastic or mylonitic deformation zones. We propose a model of fracture evolution through time decomposed into four stages.

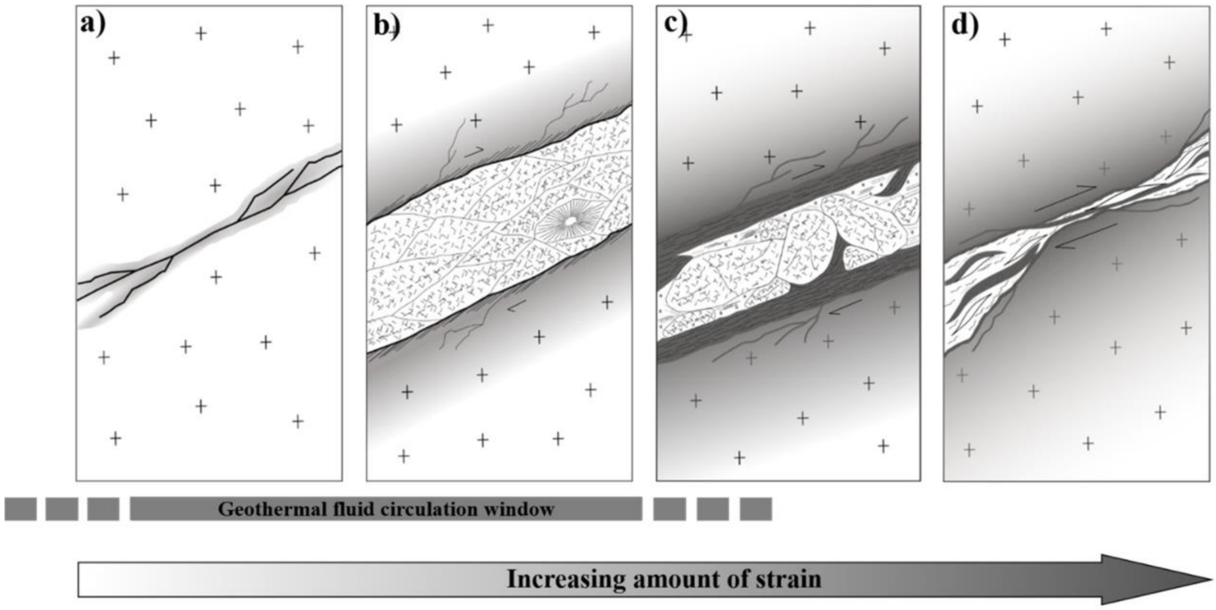


Fig 2: Schema showing the evolution over time of a quartz vein following a dextral shear deformation. a) The initial stage with creation of a fracture; b) Fracture opening filled by geodic quartz due to fluid circulation, containing opened cavities and developing an incipient alteration front; c) Increase of a shear deformation developing cataclastic layers of clays and oxides at the border of the vein, reducing the quartz vein into boudins and developing a pronounced alteration front; d) the last stage corresponding to a mylonitization of the clays/oxides layers and of the quartz due to a high degree of deformation

Our fracture evolution model through time needs to be regarded as an input for numerical modeling like coupled Thermo-Hydro-Mechanical-Chemical model to gain realistic understanding of fractured granite reservoir type's evolution. This study will allow to know with precision where a power plant can be built at the European scale with a minimum environmental and financial impact.

Young researcher:

ARMAND POMART (MASTER STUDENT AT UNILASALLE - FRANCE)

Modelling of Fractured Granitic Geothermal Reservoirs: Use of High-Resolution Data in Discrete Fracture Networks and a Coupled Processes Modeling Framework

Ghislain Trullenque [1], Rishi Parashar [2], Armand Pomart [1] and Mohammad Javad Afshari Moein [3]

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The MEET project (Multidisciplinary and multi-context demonstration of EGS exploration and Exploitation Techniques and potentials) is an interdisciplinary study aimed at the improvement of Enhanced Geothermal System (EGS) technology across Europe. Our work contributes to the project in the form of a 3D structural model and Discrete Fracture Network (DFN) analysis, coupled with multi-physics models along key transects, of an analog for the Soultsz-sous-Forêts reservoir (Upper Rhine Graben, France). The chosen analog site is in the Noble Hills (Death Valley CA, USA), an arid region of near total outcrop exposure, making it ideal for Structure from Motion-Multi-View Stereo (SfM-MVS) photogrammetry. In comparison to the Soultz-sous-Forêts reservoir, the Noble Hills has a similar granitic lithology, which has been fractured and hydrothermally altered. The front of the range is bounded by the Southern Death Valley Fault Zone (SDVFZ), a regional transform fault, which places Tertiary sediments against granite. SfM-MVS models were produced from a combination of ground-based, unmanned aerial vehicle (UAV), and aerial photography. This multi-scale approach of image collection provided resolutions ranging from cm to dm scale. Planar feature extraction was conducted using a combination of multi-point analysis and automatic facet detection with postprocessing. This planar data was extrapolated to construct a geometric model of the Noble Hills fracture network and ultimately create a representative 3D DFN model. Given the range of fracture size and relative complexity of fracture network, we implemented multiple workflows to address different aspects of the project. The DFNs were generated in 3D using a deterministic approach by projection of fracture planes on orthogonal 2D slices allowed for computation of anisotropic hydraulic conductivity tensor. Preliminary results of our fluid flow models highlight the need for understanding the multi-faceted interactions within a hydrothermal system, including temperature, stress field, and fracture geometry. In addition, given the inherent issues of oversimplification, we believe that future analog studies will benefit from adopting a hybrid DFN and a coupled multiphysics modeling approach to more accurately capture data trends across different scales.

Young researcher:

BAPTISTE LEPILLIER (PHD STUDENT AT DELFT UNIVERSITY OF TECHNOLOGY - NETHERLANDS)

Modeling Hydraulic Fracture stimulation and interaction with Complex Natural Fractures Framework in an enhanced geothermal system (EGS) context

Baptiste Lepillier[1], Alexandros Daniilidis[1], Anita Torabi[3], Eivind Bastesen[4], Francesco Parisio[2,5], Juliane Kummerow[2], KeitaYoshioka[5], Nima Doonechaly Gholizadeh[6], Óscar García[7], Pierre-Olivier Bruna[1], Richard Bakker[1], Walter Wheeler[4], David Bruhn[1,2]

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[2. GFZ German Research Centre for Geosciences, Telegrafenberg, Potsdam, Germany]
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[5. GFZ German Research Centre for Geosciences, Telegrafenberg, Potsdam, Germany]
[6. ETH Zürich, Sonneggstrasse 5, Zurich, Switzerland]
[7. Instituto Politécnico Nacional ESIA Ticoman, Mexico City, Mexico]

Keywords: EGS, hydraulic fracture propagation, natural fractures, FEM, phase-field, scanline, Discrete fracture network (DFN), GEMex, OGS, SkaPy

The development of an EGS is one of the goals of the GEMex project, an international collaboration of two consortia, one from Europe and one from Mexico. The research is based on exploration, characterization and assessment of two geothermal systems located in the Trans-Mexican volcanic belt, Los Humeros and Acoculco. Los Humeros has been a producing field for several years, but Acoculco is yet to be developed. Thanks to surface manifestations of hydrothermal activities, the existence of a geothermal system is evident. However, two wells reached very high temperatures, but did not find any fluids. For that reason, the Acoculco Caldera is foreseen as EGS development site, hoping to connect existing wells to a productive zone.

In this study, we develop a workflow that aims at assessing the feasibility of this EGS. The approach aims at generating a realistic predictive mechanical model for fracture stimulation from the well borehole. The strength of the method stands in the combination of reliable data obtained from field work and experimental measurements on mechanical properties of the target rocks, used together to populate a numerical model.

The workflow starts with the identification and description of the surface discontinuities using the scanline survey method. These surveys are interpolated and extrapolated using the multiple point statistics method to generate geological discrete fracture networks. The results of these simulations are then evaluated in a finite element method program using a flow model for fractured media. Finally, combining the fracture flow model and the mechanical properties measured in the rock physics laboratory, the fracture propagation and its interaction with the pre-existing fracture network are simulated, using the open-source finite element method software OpenGeoSys, with the variational phase-field method for hydraulic fracture modeling.

The method offers a physically sound prediction of the reservoir flow characteristics as well as an accurate mechanical model of the fracture propagation and the pressure distribution for well borehole stimulation. Because the workflow is based on easily accessible data and thanks to its simplicity, this approach could be applied in most EGS case studies.

Tuesday 17th

Knowledge of deep geothermal heat & power in various geological settings

Kristian Bär (Technische Universität Darmstadt)

Exploration workflow for deep geothermal systems

Exploration is the first important phase of every deep geothermal project. Target of every exploration campaign is a full reservoir characterization including the determination of its structure, extent, thickness, thermal field and petrophysical, hydraulic and mechanical properties.
This lecture will introduce standard exploration workflows for deep geothermal projects in various conditions (low-enthalpy sedimentary basins, mid-enthalpy basement reservoirs for enhanced geothermal systems as well as high-enthalpy volcanic geothermal systems). Different exploration methods from low-cost fieldwork based approaches to high-cost geophysical surveys will be introduced and the main targets and outcomes of each method will be explained. Finally, the integration of the exploration data into one comprehensive model of the geothermal target will form the basis to select drilling targets and define the probability of success, which is the basis for investors' decisions and prospective risk insurances.

John Reinecker (Geothermal Engineering GmbH)

Planning reservoir stimulation, technical steps and risk mitigation

Especially EGS projects are dedicated to the exploitation of heat from reservoirs with limited permeability. For these kinds of reservoirs stimulation is part of the plan to promote economic viability of the project. Other projects not envisaged as EGS may need stimulation to further enhance or restore the connectivity of the well with the reservoir. Challenges derive from drilling the well, well design and completion, reservoir characteristics, hydrochemistry and in-situ stresses among other potential reasons.
The lecture aims to provide an overview of different techniques to enhance open geothermal systems. A focus will be on chemical treatment, its prerequisites, strategy and technical steps, as well as major risks and their mitigation measures.

Chaker Raddadi (Vermilion Energy)

Geology of the Paris Basin, Challenges and potential new opportunities for the geothermal sector in the Triassic and Dogger reservoirs

The Dogger carbonate reservoir is a well-known target in the geothermal sector within the Paris Basin. Other good quality reservoirs exist in this sedimentary basin including the Triassic clastic and dolomitic reservoirs. These are considered primary targets for oil and gas and currently producing large volumes of hot water, however they are not yet fully explored for the geothermal activities.

The purpose of this course is to provide a geological review of the main Dogger and Triassic reservoirs within the Paris Basin and show few new opportunities for the geothermal sector in these reservoirs.

Yves Vanbrabant (Geological Service of Belgium)

The role of anisotropy in geothermal systems (Meta-sedimentary rocks)

The material anisotropy refers by definition to the variations of properties along different axes. Geological materials and sedimentary rocks in particular are prone to exhibit anisotropy of properties, such as the sonic velocity, the thermal conductivity or the permeability. The origin of these axial variations in (meta-)sedimentary formations is frequently related to the sedimentation and compaction processes, but the anisotropy can be in turn be affected by other events such as the development of a tectonic fabric (e.g. cleavage, faulting). During this lecture, we will explore the different properties affected by anisotropy processes through a series of study cases. The latter will be illustrated through practical exercises. In the second part of this lecture the impact of material anisotropy on the geothermal reservoir behaviour will be further studied under the angle pro’s and con’s.

Required equipment/software: the participants will bring their computer with Excel software installed (or similar). They will also need to use the R language and possibly to install some packages. Hence the participants are required to have the administrator rights on their computer.

Young researcher:

INES RAIES (PHD AT CY CERGY PARIS UNIVERSITÉ/IFPEN - FRANCE)

Role of clay minerals in injectivity related to sandstones reservoirs

I.Raies[1,2], B. Ledésert[2] , E. Kohler[1] et M. Fleury[1]

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[2] GEC, 1 rue Descartes, 95000 Neuville-sur-Oise, France.

The Paris Basin has been exploited since the 1970s for its geothermal potential in the carbonate reservoirs of the Dogger, whose current saturation leads us to consider exploiting the clays and stone reservoirs of the Triassic. However, this process is currently risky due to injection problems reported in the 1980s, which have not yet been fully understood. The objective of the thesis is to provide elements of understanding of the industrial problem of capping geothermal wells during the reinjection of filtered brines. This clogging is mainly due to the clogging of the pores by deposition of colloids present in the geothermal fluid. The colloidal particles transported can be exogenous (corrosion products, bacterial phenomena) or endogenous (remobilized clays).

a)

b)

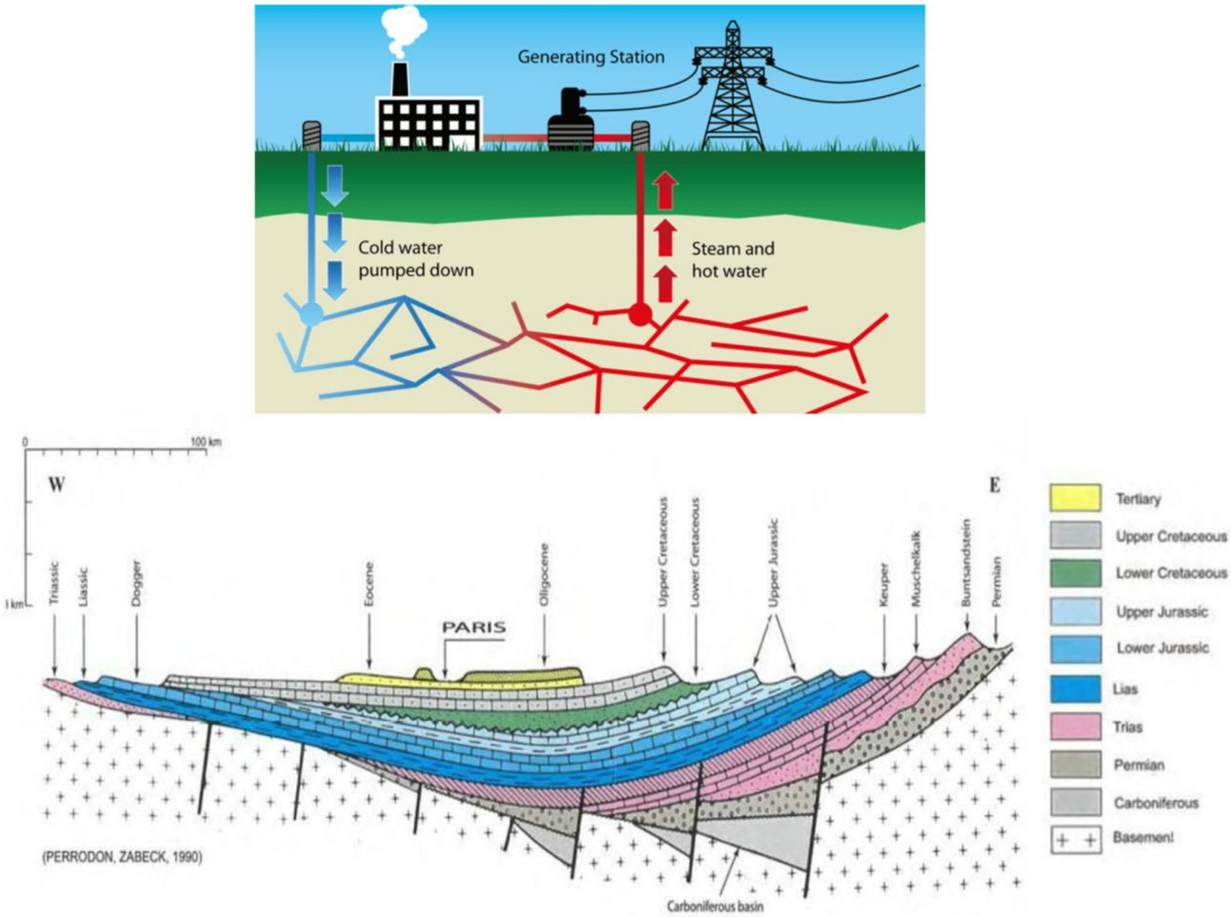


Fig. (a) Operating principle of a geothermal operation (source: BRGM). (b) Simplified geological section of the Paris Basin (Perrodon A., 1990)

In this thesis, we are interested in the role of clays in reinjection. To achieve this objective, the petrographic and mineralogical characterization of representative natural samples of Chaunoy sandstones will be carried out using X-ray diffraction, scanning and transmission electron microscopy to identify the nature, texture and quantity of all minerals. The analyses will be completed by microscopic imaging in pore-scale X-ray tomography or FIB-FEG-SEM. The samples will then be studied in the form of particles dispersed in brines and in massive form in experiments under fluid flow in porous media. The aim of these experiments will be to account for the interactions between the mobile particles and the porous medium in order to identify the causes of clogging. This thesis will thus contribute to the identification of the geological facies least adapted to geothermal processes and to define the conditions of optimal exploitation of geothermal resources.

Young researcher:

NATALIA AMANDA VERGARA (PHD AT ROMA TRE/IFPEN – ITALY/FRANCE)

Joint application of fluid inclusion and clumped isotope (Δ47) thermometry to burial carbonate cements from Upper Triassic reservoirs of the Paris Basin

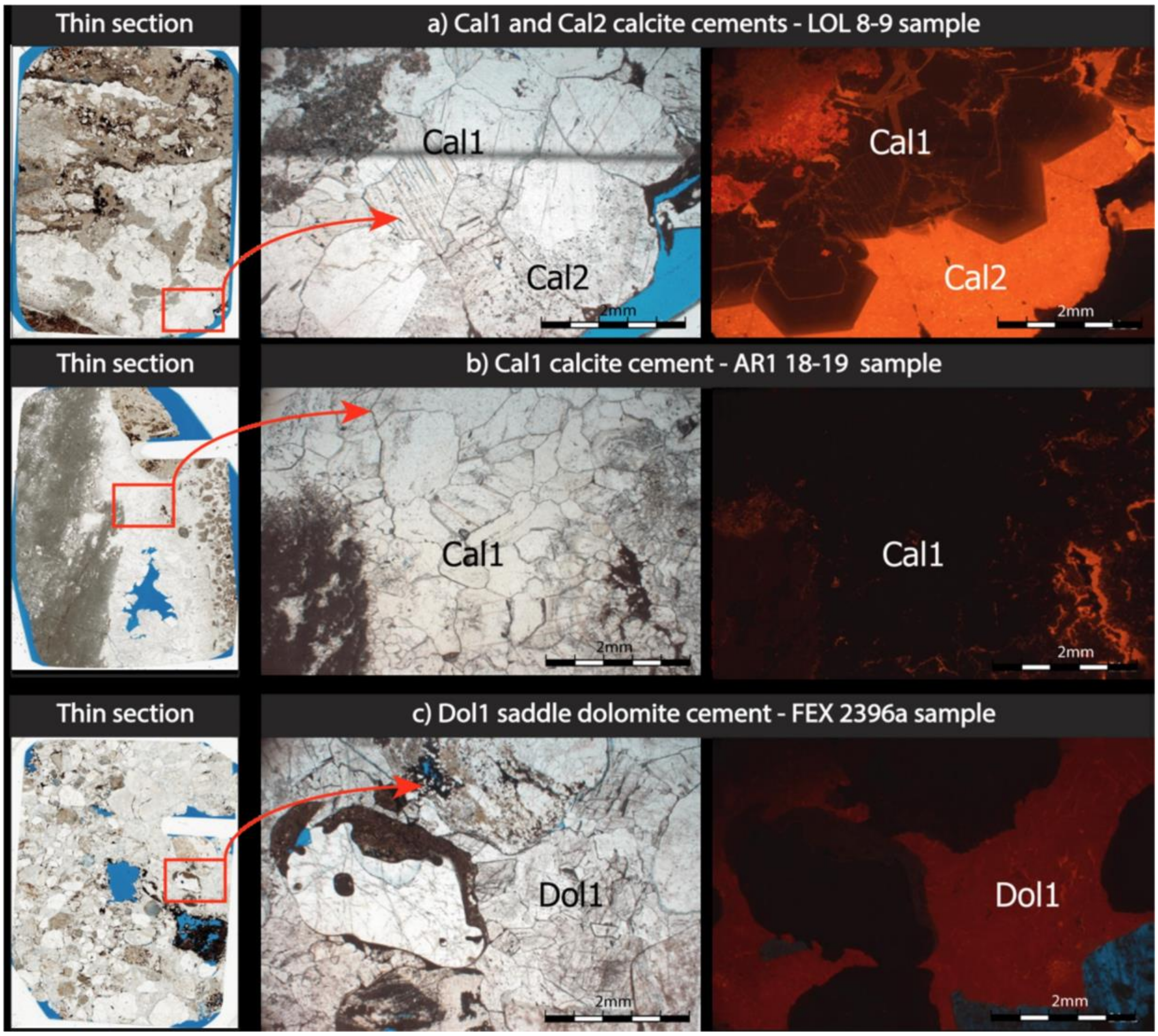
Vergara Natalia Amanda [1,2,3], Gasparrini Marta[2,4], Corrado Sveva[1], Bernasconi Stefano[5]

1. Università degli Studi Roma Tre, Rome (Italy);
2. IFP Energies nouvelles, Rueil-Malmaison (France);
3. Sorbonne Université, Paris (France);
4. Università degli Studi di Milano, Milan (Italy);
5. ETH, Zurich (Switzerland);

A realistic reconstruction of the time-temperature history of sedimentary basins is critical to understand basin evolution and to predict oil maturation and migration (oil & gas appraisal) as well to assess reservoir quality (geothermal exploration).
Carbonate rocks undergo diagenetic processes that modify their mineralogical and petrophysical properties. Understanding the temperature at which those processes occur and determining the geochemistry of the driving fluids is critical to constrain their occurrence and evolution in space and time.
Here, we put to the test the joint application of two independent techniques: the traditional fluid inclusion microthermometry (FIM) and the more recent clumped isotopes thermometer (Δ47). We compare thermal information acquired by Δ47 thermometer and FIM on diagenetic carbonates having precipitated at temperatures between 60°C and 130°C in Upper Triassic reservoirs (depths of 1820-2450 m) from the well-known Paris Basin, and having suffered 120°C during maximum burial for about 20 Ma.
A conventional diagenesis study (petrography, O-C isotope geochemistry) has been accomplished in samples from three different cores drilled in carbonate-cemented siliciclastic reservoir units of Norian age (Grés de Chaunoy Formation) and located in the northern part of the basin depocenter. A complete cement paragenesis was reconstructed highlighting three different burial cements: two non-ferroan blocky calcite phases (Cal1 and Cal2) and one non-ferroan dolomite phase of saddle type (Dol1). The progressively more negative δ18Ocarb suggests a possible increase in temperature, going from Cal1 to Dol1, whereas the consistently negative δ13C could indicate the involvement of continental fluids.
FIM indicates homogenization temperatures (Th) spanning from 60°C to 95°C (mode 67.5°C) for Cal1, 70°C to 110°C (mode 84°C) for Cal2, and 100°C to 130°C (mode 115°C) for Dol1. Δ47 measurements overall reveals lower temperatures for calcite cements,

indicating probable thermal reequilibration of the fluid inclusions, and a fairly similar temperature for the saddle dolomite cement. Uncertainties in the temperatures obtained through FIM and Δ47 thermometry and in the successively calculated ̣18Ofluid, may lead to an erroneous assessment of the time of precipitation of the different diagenetic phases and to an erroneous thermal history and fluid-flow reconstruction.

This work emphasizes the necessity of better understanding the limitations and applicability fields of these thermometric tools, especially when applied to burial diagenetic phases precipitated at temperatures above 100°C and/or in reservoirs having experienced temperatures in the gas window.



Thin section scan and microphotographs (CL and transmitted light) showing the major petrographic features of the investigated diagenetic cements for the three different analyzed cores. From left to right
column: thin-sections scans; analyzed cement phase in transmitted-light; analyzed cement phase in CL. a) Cal1 consists of blocky crystals and displays a non-luminescent response under CL. Rock sample: LOL 8-9 (~2008.5m depth), Longueil1b core; b) Cal2 is a blocky calcite with a uniform bright-orange CL pattern.
Rock sample: AR1 18-19 (~1918.5m depth), Arsy1 core; c) Dol1 is a saddle dolomite dull red under CL and with curved crystal faces. Rock sample: FEX2396a (2396m depth), Feigneux1 core.

Young researcher:

KATJA SCHULTZ (MASTER STUDENT AT TECHNISCHE UNIVERSITAT DARMSTADT - GERMANY)

Lab analysis of permeability enhancement by chemical treatment of fractured granite samples (Cornubian Batholith) of the United Downs Deep Geothermal Power Project

Katja E. Schulz, Aysegul Turan, Kristian Bär, Ingo Sass

Technische Universitat Darmstadt, Institute of Applied Geosciences, Department of Geothermal Science and Technology, Schnittspahnstrasse 9, 64287 Darmstadt, Germany

Keywords: Enhanced Geothermal Systems (EGS), fractured granite, Core Flooding Experiments, Cornubian batholith

In the framework of the European Union-funded project MEET (Multidisciplinary and multi-context demonstration of EGS exploration and Exploitation Techniques and potentials, grant agreement No. 792037), the Technische Universitat of Darmstadt is research partner of the United Downs Deep Geothermal Power Project in Redruth, Cornwall. The study area is the Carnmenellis granite, one of the onshore plutons of the Cornubian Batholith. It is characterised by a strong geothermal anomaly, caused by radioactive decay of U, Th and K in granite. A hydrothermal dublet-system with the production well UDl, reaching a depth of 5058 m TVD (5275 m MD), and an injection well UD2 reaching 2214 m TVD (2393 m MD), is drilled for geothermal energy production of approximately 3 MW of net electricity. Geological target of this project is the 200 m to 500 m wide-, more than 15 km long-Porthtowan strike-slip Fault Zone, which strikes NNW-SSE and links these two wells vertically (Law, Cotton, & Ledingham, 2019).

Within the scope of this study, the enhancement of rock permeability by acidification is analysed. A set of different analytical methods, such as XRD, ICP-MS, thermoscanning, helium-pycnometry, helium-permeametry and sonic velocity, is used to characterise the samples petrologically and petrophysically before and after chemical treatment in high temperature autoclave-experiments and Core Flooding Tests. In the chemical treatment experiments, the samples are placed in autoclaves together with acids at 150°C for 24 hours. The acids used are 15 % HCl and 'white acid', consisting of 15 % HCl and 3 % HF, which resembles Regular Mud Acid, commonly employed in chemical well stimulation. In the Core Flooding Tests, which are conducted at the labs of Fangmann Energy Services, the chemical blends SSB-007 and SFB-007 are circulated through the cores at a temperature of 150 °C and a confining pressure of 2500 psi. During the flow rate-controlled test, the differential pressure is logged to calculate the permeability development over time (Lummer & Rauf, 2019). SSB-007 and SFB-007 have relatively similar characteristics as the fluids used in the autoclave-experiments. The analysed samples are outcrop analogue samples taken from six different locations around the Cornubian Batholith, as displayed in Figure 1. They have a relatively high geochemical conformity with the Carnmenellis Granite (Simons, Shail, & Andersen, 2016) and include veins, which allow analogies with fractured- and hydrothermally altered zones around the fault zones encountered in UD1. The Core Flooding Tests on these samples have resulted in an increase of the core permeability by a factor ranging from 4 to 50. In addition, cuttings, from potential target zones in UD1, which have been identified by ultrasonic borehole log interpretation (UXPL), fluid lasses, gas intrusions and anomalies of the geothermal gradient, are analysed with a focus on geochemical changes during autoclave experiments to be able to transfer the results directly to the scenario of a chemical treatment of UD1.

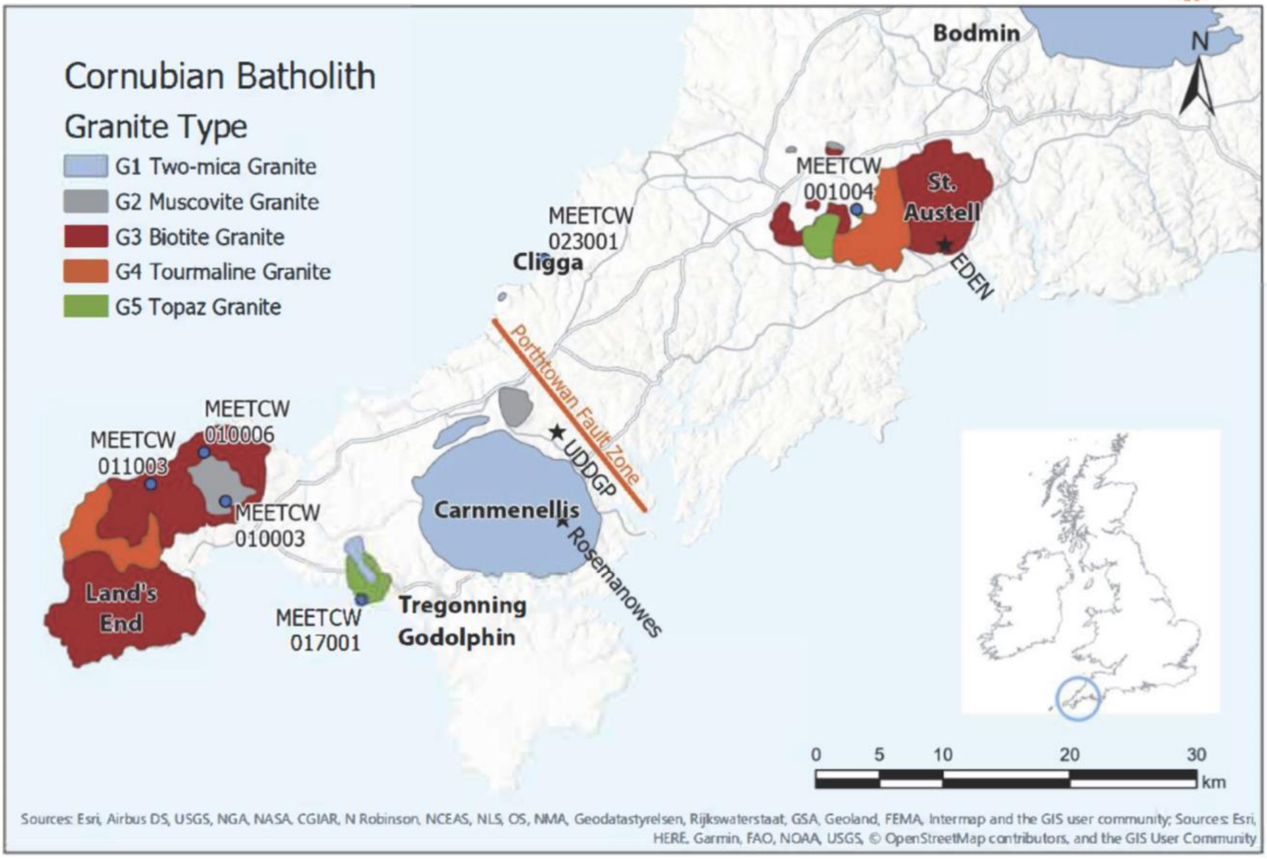


Figure 1: Map of sampling locations and relevant geothermal project sites in Cornwall. Granite types andPorthtowan Fault Zone simplified after Simons et al. (2016) and Law et al. (2019).

References

Law, R., Cotton, L., & Ledingham, P. (2019). The United Downs Deep Geothermal Power Project. EGC. Den Haag.

Lummer, N., & Rauf, O. (2019). Premium Treatment System for Granite and Sandstone Formations - Fluid Development and Field Trial in a Geothermal Well. EGC. Den Haag.

Simons, B., Shail, R., & Andersen, J. (2016). The petrogenesis of the Early Permian Variscan granites of the Cornubian Batholith: Lower plate post-collisional peraluminous magmatism in the Rhenohercynian Zone of SW England. Lithos (260), pp. 76-94.

Young researcher:

AYSEGUL TURAN (PHD STUDENT AT TECHNISCHE UNIVERSITAT DARMSTADT - GERMANY)

A Coupled THC Modelling Approach Based on Outcrop Analogue Samples and Borehole Data from the Variscan Crystalline Basement in Cornwall (UK): A Case Study for EGS

Aysegul Turan[1], Kristian Bär[1], Ingo Sass[1,2]

[1] Technische Universität Darmstadt, Institute of Applied Geosciences, Group of Geothermal Science and Technology, Schnittspahnstrasse 9, 64287 Darmstadt, Germany

[2]Darmstadt Graduate School of Excellence Energy Science and Engineering, Otto-Berndt-Strasse 3, 64287 Darmstadt, Germany

Keywords: fractured granite, Enhanced Geothermal Systems (EGS), Variscan orogeny, Cornubian batholith, United Downs Deep Geothermal Power Project (UDDGP), MEET EU Project

The EU H2020 funded 'MEET' project ('**M**ultidisciplinary and multi-context demonstration of **E**GS exploration and **E**xploitation **T**echniques and potentials', grant agreement no:792037) assesses the four different geological settings of Variscan basement as reservoir rocks for potential EGSs. The study presented here, as a part of MEET project, specifically focuses on the Cornubian batholith in SW England chosen as representative of the crystalline Variscan basement not overprinted by younger tectonic regime.

With the ambition to increase the clean energy share in United Kingdom's energy portfolio, Cornwall has been the focus of deep geothermal resource studies starting from 1980s with the Rosemanowes Hot Dry Rock project conducted in the region and continuing today with the United Downs Deep Geothermal Power Project (UDDGP), the first deep geothermal power project of UK. The main reason of this interest is the high heat flow arising from the radioactive decay of U, Th, K elements within the Cornubian batholith.

The present work aims to investigate the untapped geothermal potential of fractured Cornish granite in more detail. To do that representative samples from the Cornubian Batholith were taken from the outcropping Land's End, St. Austell and Carnmenellis pluton. 47 granitic samples with a total weight of 1 ton, were collected from fractured and/or hydrothermally altered areas of 19 outcrops representative of the fracture and fault zones within the United Downs wells. 254 cores with different diameters were drilled in the HydroThermikum Research and Teaching Laboratory of Technical University Darmstadt to do a comprehensive petrophysical and rock mechanical characterization. 50 samples were selected to prepare thin sections, required for a detailed petrographic analysis including degree of weathering or alteration and fluid inclusions.

The UDDGP was selected as the demonstration site for the MEET project and data was provided by its two recently drilled wells (UD-1: 5,275 m MD, UD-2: 2,393 m MD) targeting the Porthtowan Fault zone (PTF), which is a 40 km long NW-SE trending strike-slip fault. Drill cuttings from 44 sections representing 10 m intervals each, were taken from the potential target zones between 3,980 and 5,275 m MD in UD1 with intense fracturization, fluid losses, gas intrusions and/or anomalies in the geothermal gradient. Additional data was available from the Rosemanowes hot dry rock project site, which within MEET was selected as reservoir analogue site; this included fracture network characterization from

well logs as well as hydraulic parameters of the deeper sections drilled into the Carnmenellis granite.
We defined a conceptional workflow for a coupled thermo-hydraulic-chemical model, which is planned to be set up using FRACMAN and COMSOL to evaluate and analyze whether a sustainable operation of the reservoir is possible and what flow rates can be achieved with realistic pressure differences between producer and injector. Additionally, time till thermal break through assuming different values for fault zone permeability shall be assessed.

If the natural productivity is insufficient part of our task within MEET is to develop a chemical stimulation strategy. Therefore, lab investigations on how to enhance the fluid flow in fractured granite, based on the state-of-the-art techniques for chemical stimulation developed in ongoing EGS projects in the Upper Rhine Graben, e.g. Soultz-sous-Forêts and Rittershoffen have been applied. These lab experiments aim to quantify the possible permeability increase by chemical treatment of the fractured samples and are designed to select the best chemical blend for increasing permeability at reservoir scale.

Measurement of the petrophysical (grain density, permeability, bulk density and porosity, compressive and shear velocity, thermal conductivity, thermal diffusivity, heat capacity and radiogenic heat production) and rock mechanical properties (uniaxial compressive strength, Poisson's ratio, Young's modulus, bulk modulus and compressibility as well as tensile strength, shear strength, cohesion, coefficient of friction and shear modulus and finally Biot and Skempton coefficients) on outcrop analogue samples are still ongoing.

Planned future work includes, but is not limited to, petrographic analyses of thin sections made out of drill cuttings of the production well UD-1 and outcrop analogue samples. Additionally, petrophyscial and petrographic analyses of sidewall cores, planned to be taken in March 2020, will be performed. This input data will be used for a statistical parametrization of the numerical model of the system.

Wednesday 18th

Promoting EGS across Europe: mapping best locations for future installations

Keynote lecture:

Adele Manzella (Consiglio Nazionale delle Ricerche)

Social aspects for geothermal energy development and policy implications

Energy transition, and with it the geothermal market development, regards not only the adoption, strengthening and integration of various energy technologies: it implies also a different way to embed energy matters in and for the society as a whole. Many renewable energy technologies are facing concern, and industrial development is sometime slowed down by social opposition, a problem which is felt in the geothermal sector but that in most cases originates by a lack of trust caused in very different contexts. Nowadays the transparency and openness of project developments, i.e. to the opening up of the project to as much stakeholders as possible, thus strengthening knowledge and trust and legitimising the activities carried out, is accompanied by the involvement of citizens, i.e. the engagement of citizens who are directly and locally affected by the project. New forms of debate and democratic procedures are therefore required for project development, while pursuing profits (shareholders' interest), and creating value for all society (stakeholders' interest).
We will investigate how social engagement is pursued in different part of the world, will discuss if and how it is effective and will explore its link to policy in Europe.

Keynote lecture:

Margaret Krieger (International Geothermal Association)

IGA Overview / Risk assessment in geothermal : challenging our perception

In her talk, Margaret will give an overview of the International Geothermal Association (IGA) and will showcase some opportunities the organization could provide for young students and researchers. The main part of the talk however will be dedicated to non-technical risk assessment in geothermal: participants will be invited to look at the risk from the probability angle and at the end of the talk will get a better understanding on how uncertainties affect geothermal development. The talk aims at complimenting technical discussion and would be helpful to anyone who would like to have a broader understanding of risk issues.

Bianca Wagner (Georg-August Universität Göttingen)

Concepts and data sources for mapping deep geothermal resources throughout Europe

Each geothermal projects is embedded in a geoscientific, economic, technical, legal and social framework, which can be described by parameters and interlinked datasets. The latter are a fundamental base for taking strategic decisions in terms of resources, risks or costs, for classifying, for evaluating or for comparing geothermal projects as well as for defining the project readiness level.

In an early project phase, a wide range of datasets is already needed to find promising sites or to foster commencing initiatives. Even before the project start itself, the geothermal potential of a certain area or distinct region has to be determined by the analysis of spatial and non-spatial datasets. There are several types of geothermal potential definitions in use depending on the subjects that are taken into account. A comprehensive approach, for instance to define the economic or technical potential of an area, comprises broad subsurface and surface datasets. Furthermore, the identified potential has to be matched with the current and future user’s demand for heat and/or power and their location, as both are linked to a certain area.

The content of the course is aimed to give the participants insights into this complex context and to introduce pathways to data sources and tools as well as to critically consider and discuss the recent situation in terms of data availability in Europe.

In the first part, we will discuss the types of geothermal potentials and the common classification schemes, which are deployed to categorize geothermal projects. Different potential maps and visualization approaches will be compared to select appropriate ways to express the potential in 2D or 3D. Finally, we will identify and rate major and minor “geothermal parameters” and to figure out their typical data types, data formats and data producers.

In the subsequent group work, the participants will investigate in small teams the availability and quality of manifold parameters on a national and a European scale by accessing a wide range of platforms, databases and knowledge hubs. Additionally, the teams will test online tools that were designed to map or estimate the geothermal potential. The findings will be presented shortly to the audience by each team.

The joint outcome of all teams will be critically discussed and examined in terms of data types, homogeneity, coverage, accuracy and informative value to identify highly recommendable data sources and tools, but also to define gaps und inconsistencies. Based on these results, we will work out an appropriate potential estimation approach that can be applied to map resources throughout Europe and that will rest on reliable datasets. Finally, we will sum up the recent situation by collecting benefits and favourable trends on the one hand side as well as drawbacks and bottlenecks on the other. At the very end of the course we will gather new ideas and solutions to delineate future steps, which might be projects, cooperation initiatives or communication activities.

Notice: Laptops and internet access (LAN or WiFi) are needed for this course.

Bernd Leiss (Georg-August Universität Göttingen / Universitätsenergie Göttingen GmbH)

An unorthodox exploration and exploitation strategy for the development of an unconventional geothermal reservoir – the Göttingen University campus demo site

Heat supply for the existing district heating system of the Göttingen University Campus is covered by a University-owned gas based heat and power station. For the conversion into a sustainable heat supply, deep geothermal energy has the most promising theoretical potential. However, the geological setting below Göttingen is highly complex in terms of lithology and structure. In addition, the data base is quite weak. However, the complexity offers on the other hand the chance of multifaceted possibilities of target horizons and has the potential for the integration of different systems. After the introduction of the surface infrastructural and the subsurface geological setting including own recent seismic lines, we will develop exploration and exploitation strategies in several groups as an exercise. Finally, we will together discuss different approaches considering chances and barriers in view of the geological, engineering, legal, sociological, political and economical setting of the real life lab – the Göttingen campus demo site. A challenge which needs unorthodox thinking on one hand and convincing stakeholders on the other hand – always having the risks in mind.

Young researcher:

KATHERINE FORD (PHD AT GEORG-AUGUST UNIVERSITÄT GÖTTINGEN - GERMANY)

Fracture Network Characterization of the Culm Fold Zone (Western Harz Mountains – Germany) as a Mean to Extract Geothermal Reservoir Parameters

The focus of this study is to characterize an analogue site for the Variscan metasedimentary and metavolcanic Variscan basement, the potential target reservoir in an unconventional geological setting for the geothermal project of the University of Göttingen. The main outcome of which is to supply district heating for the entire campus. From interpolation of comparable units in the Rhenish Massif with the Harz Mountains, it is likely that the boundary that separates the Variscan autochthonous from the allochthonous zone is striking through the subsurface of the city area of Göttingen. For that reason the analogue site for this project has been chosen as the Western Harz Mountains, paired with the reasonable outcrop situation.

To understand and comprise the complex structural parameters that may be found in the expected alternating slate and greywacke units beneath the surface of Göttingen, a 3D conceptual structural model of the Variscan basement must be created as the first step. This contribution will focus on the interactions and changes of different structural parameters across the typical Variscan fold and thrust belt at outcrop scale. To accomplish this, intensive field campaigns and photogrammetry sessions are undertaken for detailed data collection on changes in parameters such as the fracture network, mineralization and lithology across the primary fold and thrust structure.
The methodology presented focuses firstly on the simplification of such a complex geological setting by characterising 7 main structural situations (presented in fig.1), and 5

main lithological situations. Then from this, the characterization of the fracture network at each of these defined setting through topological analysis. The main parameters defined within the study are connectivity, intensity and level of mineralisation. This methodology allows a basis for the understanding of the complexity of deformation exhibited in the Variscan Fold-and-Thrust belt.

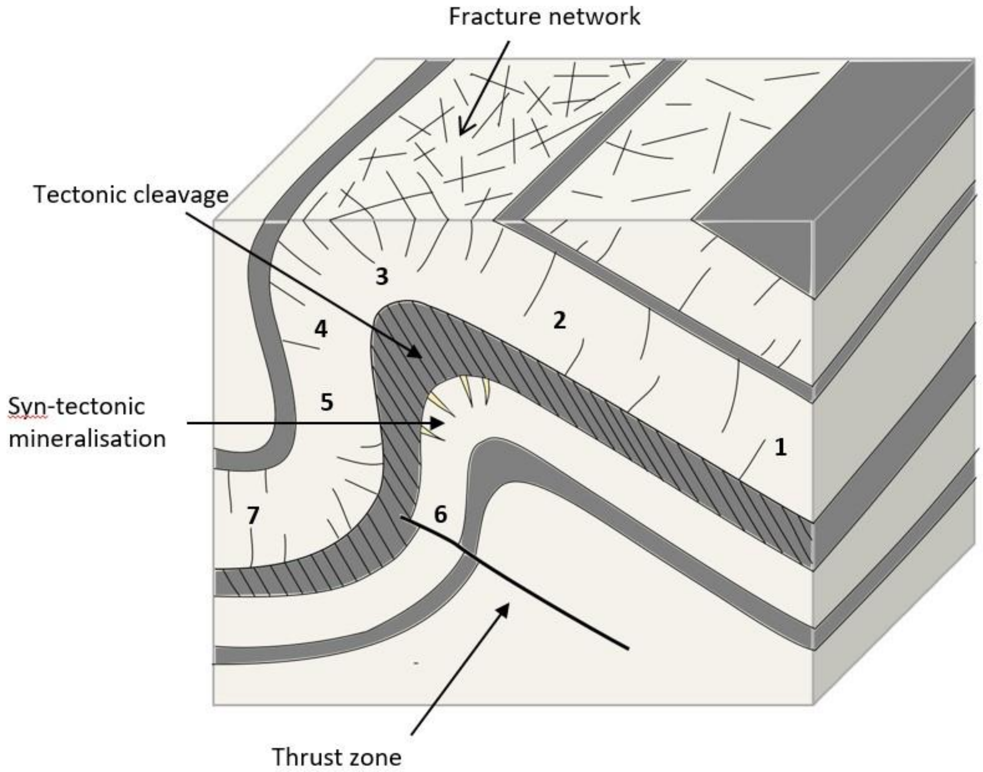


Fig 1. 3D block diagram indicating the simplification of the complex structures and lithologies seen within the Harz Mountains. Each number representing a defined structural situation. 1) back limb far from hinge. 2) back limb close to hinge. 3) fold hinge zone. 4) overturned forelimb close to hinge. 5) overturned forelimb far from hinge. 6) thrust zone. 7) relatively undeformed forelimb.

Due to the complexity of the lithology and structures exposed in the Western Harz Mountains, a total of 29 outcrops have been categorized, and fracture trace maps have been collected at each defined category. As well as this, a 2.5D approach to fracture network characterisation has been undertaken. Trace maps are created on the bedding plane itself, and adjacent to the planes, this allows for the more holistic quantification of the fracture networks under varying exposure orientations and through the changes in lithology. This statistical approach to data collection will allow for a more generalised view of the interactions between the fracture networks and the lithological and structural framework, such as local-scale folds and faults, which for an analogue study is more suitable.

The preliminary results of this study do show a general trend of increased intensity, level of mineralisation and connectivity towards the fold hinge and thrust zone but are however more complex than this hypothesis. A much more detailed study must be undertaken to truly understand how fracture network characteristics are affected by changes in lithological and structural variations. With a detailed characterisation of the fracture network throughout this complex reservoir this is the first step in the creation of the conceptual structural model, following this with petrophysical and chemical parameterisation derived from lab experiments, reservoir models and EGS-exploitation strategies can then be developed and the reservoir potential realised.

Young researcher:

RHADITYO ARBARIM (PHD AT TECHNISCHE UNIVERSITÄT DARMSTADT - GERMANY)

Implementation of hybrid discrete fracture network (DFN) and equivalent porous medium (EPM) approach: an initial step for thermo-hydro-mechanical simulation of low temperature injection at the Soultz geothermal project

Rhadityo Arbarim, Kristian Bär, Ingo Sass

Institut für Angewandte Geowissenschaften, Technische Universität Darmstadt

The study of fluid and heat flow in Enhanced Geothermal Systems (EGS) has become an increasingly important topic in recent decades to understand and manage these deep and hot reservoirs. EGS relies on the creation of the fracture network to assists the fluid flow as well as heat exchange from the host rock to the fluid in the fracture network. The understanding of DFN thus is of principal importance to the success of EGS. This study focuses on the EGS field in Soultz, France, where the heat exchange takes place in fractured crystalline basement.

Many studies about modeling in Soultz have been conducted to understand the hydrothermal behavior. However, none of them has clearly addressed the importance of anisotropic permeability tensor as a result of complex fracture networks. In Soultz, major fracture zones are confirmed by several methods, for instance, core, induced seismicity, vertical seismic profile, and image log analyses even though the resolution is limited only to the vicinity of the borehole. Stochastic methods are then employed to generate DFN away from the borehole to identify the communication among the wells on one hand.

On the other hand, a highly fractured domain is often beyond commercial simulator's capacity, whereas the demand for high accuracy of the fracture networks remains crucial to simulate hydro- or thermos-mechanically coupled processes. In this study, the hybrid DFN-EPM method is implemented to capture the effect of anisotropic permeability tensor while preserving the explicit representation of the main fractures. The fundamental idea of hybrid DFN-EPM is to keep the confirmed fractures as DFN and convert the stochastic DFN into EPM.

This study aims to evaluate the effect of colder water injection with respect to the hydrothermal behavior of the highly fractured EGS reservoir in Soultz. As a further step, this model allows the investigation of mechanical behavior as a preliminary basis of the forecast of induced seismicity during water injection in Soultz or of the effect of thermoelasticity on the long-term permeability development.

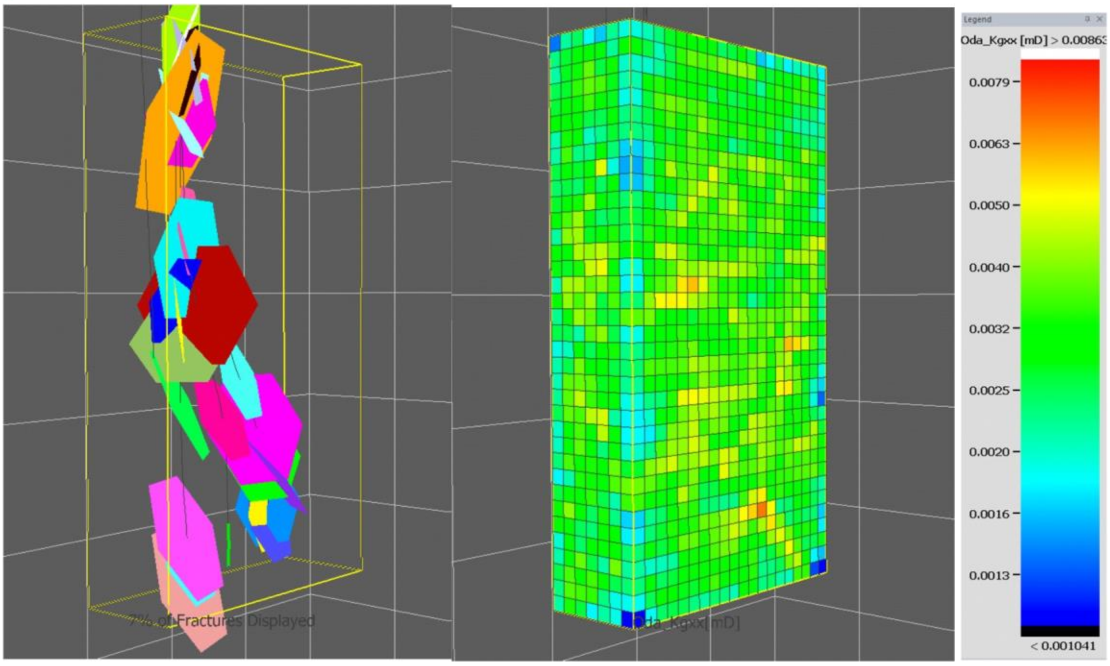


Fig 1 : 29 deterministic fractures defined by Sausse et al. 2010 (a), and upscaled permeability using the Oda (1984) approach in x direction derived from a DFN created based on the GPK-4 set 1 fracture networks (b)

Young researcher:

ANVAR FARKHUDTINOV (ASSISTANT PROFESSOR AT BASHKIR STATE UNIVERSITY - RUSSIA, AND INVITED RESEARCHER FELLOW AT CY ADVANCED STUDIES)

A numerical modelling approach for geothermal waters sustainable use (the Khankala geothermal field case)

Nowadays, geothermal waters have become an important form of energy and many researchers have put to the forefront the issue of “sustainability” of the geothermal reservoir development. “Sustainability” of the geothermal waters use is a problem of primary importance, the solution of which requires an integrated approach. Sustainable management of resource utilization is possible with an adequate development strategy as “… for each geothermal system and for each mode of production there exists a certain level of maximum energy production, below which it will be possible to maintain a constant energy production from the system for a very long time (100–300 years)…” (Axelsson et al., 2001).

Reinjection of the used fluid during geothermal reservoir exploitation is the most commonly used exploitation method. It allows minimizing the possible negative effect on the environment and maintaining the reservoir pressure and therefore the initial high flow rates. However, it has a major disadvantage – a gradual temperature decrease in an aquifer, which needs to be taken into account. The most effective methods assessing this disadvantage are based on numerical modelling, which has been actively implemented in all areas of science. Modelling is used to simulate the behavior of complex geothermal reservoir system under different exploitation conditions and predict temperature change. It helps to manage problems of geothermal water exploitation and achieve sustainability.

Modelling was used during the most recent Russian geothermal project – implementation of Khankala geothermal plant (Figure 1).

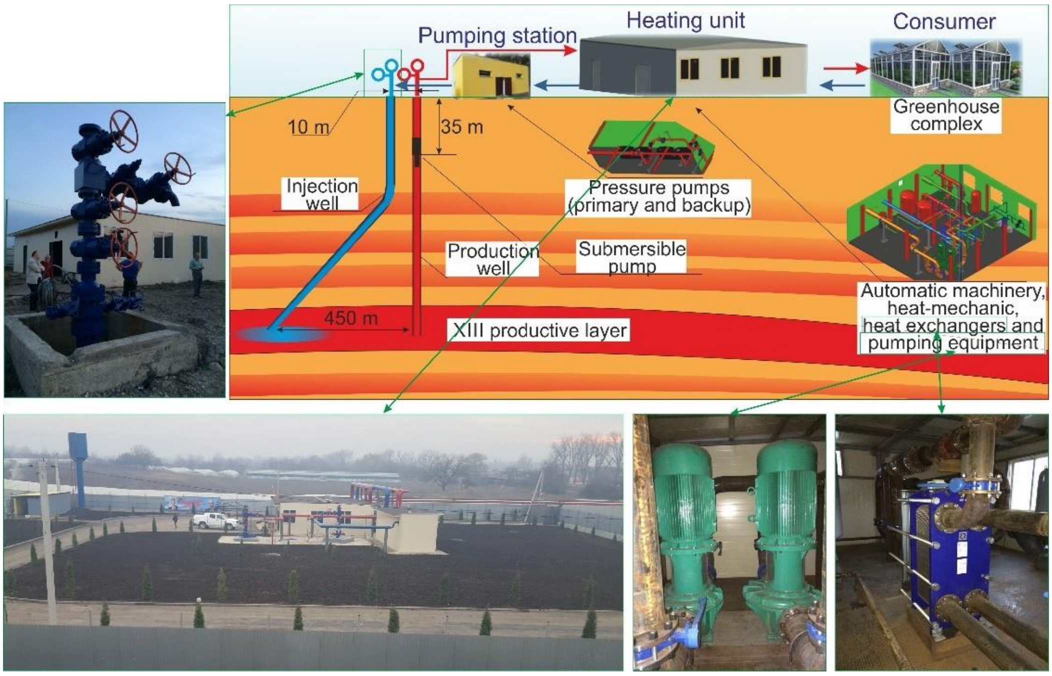


Fig. 1. Schematic drawing and photos of the Khankala geothermal plant.

The Khankala geothermal field is located within the East Ciscaucasian artesian basin, which occupies 250 000 km2. In the beginning of 2016, the Khankala geothermal plant started operating on the basis of the XIII productive layer with a thickness of 40–60 m. The capacity of the facility is 22.8 GJ/h with a greenhouse complex as a consumer. Two wells were drilled to conduct exploitation by a “doublet” system, i.e., one production and one injection well with reinjection of all cooled geothermal water back.
Based on the results of modelling, a gradual decrease in temperature in the production well after 6– 7 years of exploitation is predicted due to reinjection of used geothermal water (45°C) (Figure 2).

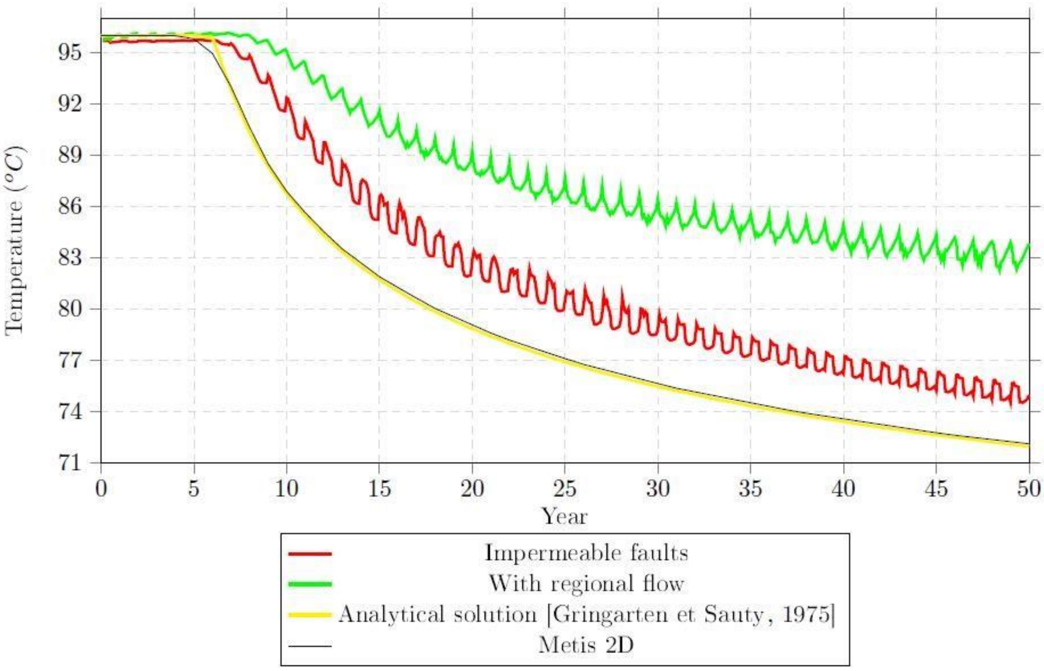


Fig. 2. The results of the modelling: temperature evolution at the production well.

One of the main advantages of the Khankala geothermal field is its multi-layered nature. Vertical extension of the cold front is therefore limited by impermeable layers, and so, reinjection in one of the main productive layers does not have an impact on others.
At the same time, in the case of significant drop in the production well temperature after some period of XIII layer exploitation, there is a possibility to drill a new “doublet” at the same territory on the resource of the highly promising IV–VII, XVI, or XXII layers, so that the geothermal plant could continue working. The resource of the XIII layer could be used again after some shut-down period considering the relatively high speed of temperature recovery. The installation and the periodic use of two or more circulation systems can be beneficial and are the only true solution of the sustainability problem in long-term operation. The sustainable use of geothermal waters is possible, but requires to choose adequate exploitation scenario and therefore numerical modelling, as it helps to forecast geothermal reservoir behavior under different conditions.

Abdelkader Aït Ouali (Researcher at CDER - Algerian renewable energy research center/ Geothermal energy team)

Algerian geothermal perspectives by field works studies

Keywords: Geothermal energy, exploration, EGS, deep reservoirs, geology, Algeria

Algerian geothermal prospective remains unexplored, thus the Algerian government aims to support research to implement a new strategy for renewable energy. Geothermal resources maps drawn in the framework of several projects will a solid basis for future development of this strategy. Geochemistry, Geology, Geophysics were used to delineate six geothermal provinces. These provinces have been classified by their geothermal potential as from low to medium enthalpy: North Western Province; North Central Province; North Eastern Province; Saharian Platform Province; Hoggar Province; South Western Province. The maximum thermal springs temperature at the surface reaches T=98°C in North Eastern province, most geothermal reservoir temperature does not exceed 130°C based on chemical Geothermometers. A global map of Main Geothermal provinces in Algeria was drawn recently updating hydrochemistry data and we calculated the geothermal potential and the flow rate.

Thursday 19th

Increase heat production: optimization of deep resources in oil wells and existing plants

Eléonore Dalmais (ES-Géothermie)

Optimization of energy valorization on EGS plant, application to Soultz-sous-Forêts demo-site

The course will be dedicated to MEET activities around the demo-site of Soultz-Sous-Forêts. It will firstly quickly present the EGS plant of Soultz, both the reservoir and surface facilities. It will then focus on MEET activities which consists in lowering the reinjection temperature in order to valorise more energy.
On surface facilities, we will discuss the knowledge gained on corrosion and scaling effects at this low temperature. We will also overlook the on-going test of mobile ORC to valorise this low temperature water into electricity.
On subsurface part, the course will focus on the hydrothermal modelling approaches to assess the impact of colder reinjection on long-term production temperature and discuss the sustainability of such system.
Finally, we will discuss the environmental impacts of EGS power plant and additional measures set up in the framework of MEET to monitor them.

Eric Léoutre (VERMILION Energy)

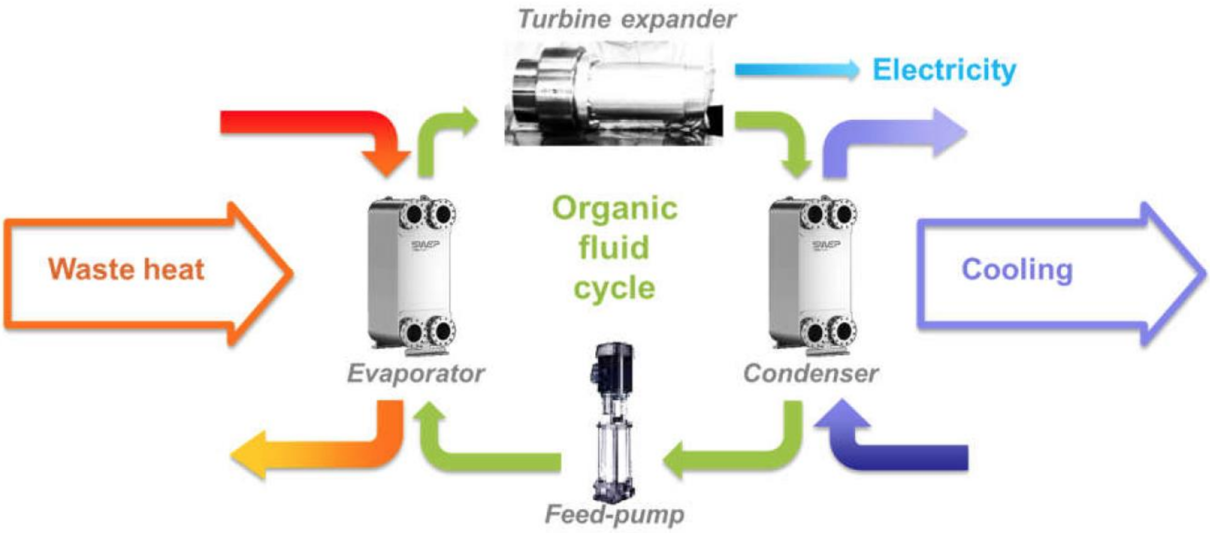
Co-production of oil and geothermal heat: opportunities and challenges.

We will consider the practical synergies of valorizing the heat produced on a so-called "mature" oil site, i.e. one that produces large volumes of water in addition to oil. Taking the example of the well portfolio of Vermilion, a French-based operator, we will see how we have inventoried the resource and then the local utilization projects . A review of subsoil risks will be presented on an identified high school heating project, in particular the optimization of flow rates and the evolution of the temperature of the deposit.

André-Charles Mintsa (ENOGIA)

ORC technology and implementation in different geological contexts

The ORC or the Organic Rankine Cycle,is a thermodynamic cycle, allowing heat to electricity conversion. The name Rankine cycle come from William Rankine, a Scottish engineer who developed the theory of steam Machine. The ORC vaporize an organic fluid having a molecular mass higher than water, and a liquid-vapor phase change occurring at lower temperature than water. This machine works based on these 2 principles. The ORC can work at low temperature, between 30° to 300°C.
ORC applications are broad and depends on the organic fluid used in the cycle. Some examples of heat sources that can be used are industrial waste, biomass combustion, geothermal heat…
The purpose of this course is to give basic knowledge of ORC technology. At the end of this course, the attendee will know what an ORC is, how to perform an ORC sizing, the pros and cons of this technology. ORC application in geothermal context will be emphasized.



Course plan

1. Introduction
2. The Story of the ORC
3. How does an ORC work ?
    a. Principle of the ORC
    b. How to select the working Fluid ?
    c. What is a Regenerative Cycle ?
    d. What is an Expander machine ?
4. How to design an ORC ?
5. Heat recovery in the geothermal context

There is no prerequisite, but knowledge of thermodynamics will help.

Vincent Lanticq (FEBUS Optics)

Fiber optics, an adaptable and cost-effective technology for monitoring geothermal reservoirs at different scales

For 30 years, optical fibers have been widely deployed for building telecommunication networks.
This silica wire, guiding light in a core as small as 9 microns, has good properties (such as ElectroMagnetic Immunity or Durability and Elasticity of anamorphous silica) making it suitable for many applications. Fiber Optic Sensing is one of them because optical fibers are intrinsically sensitive to temperature and strain. Moreover, it can be encapsulated in order to measure many other parameters. The purpose of this course is to detail this technology in the area of subsurface applications, specifically geothermal reservoir monitoring.
In this short course, we will first present the basics of fiber optic technologies in general. Then we will show how this small element can become a sensor thanks to the insertion of a local element called Fiber Bragg Grating into the optical fiber. Finally, we will present the Distributed Fiber-Optic sensing techniques: Distributed Temperature Sensing (DTS), Distributed Strain Sensing (DSS). Distributed Acoustic Sensing (DAS). Those methods use the whole length of the fiber optic itself as thousands of sensors.

Young researcher:

MARTHA NNKO (PHD AT DELFT UNIVERSITY OF TECHNOLOGY - NETHERLANDS)

Mechanical Characterization and Potential Evaluation of the Geothermal System in Songwe field, Mbeya, Tanzania

Tanzania is one of the East African countries with large amount of geothermal potential that has not been used yet and has only been explored to a limited extentThe national power system relies greatly on hydropower and natural gas. Willing to propose an alternative, the government of Tanzania has made geothermal development a priority.
The area around the city of Mbeya, located at the junction of two branches of the East African rift system has been identified as a first priority region from which two specific targets have been defined, the volcanic region of Ngozi and the half-graben of Songwe. In this study focus is made on the Songwe basin.
In geothermal exploration and development, numerical modelling is essential to understand both regional and reservoir scale processes. Key factors determining geothermal systems potential are temperature and fluid flow. Numerical models allow to constrain reservoir geological properties and fluid flow behaviour to better plan the well path design and field production. In Tanzania, only geophysical (MT and TEM), geochemical studies and field geology have been done. A need therefore arises for numerical modelling to evaluate and assess the potential of the geothermal fields which is the purpose of this study.
In order to evaluate the potential of the geothermal system in Songwe, the study approach includes the reconstruction of the geological model to get the geometry, thermal modelling, hydrothermal modelling, laboratory testing of hot springs fluid to find the chemical properties, and laboratory testing of rock samples to obtain their physical and mechanical properties.

The study presents a reconstructed geological model with the deep structure, a realistic geometry that is essential for the thermal modelling and geothermal modelling work (Figure 1). Thermal modelling with different scenarios to understand how temperature is distributed in the subsurface at a steady-state is also presented in the study and temperature values compared (Figure 2).

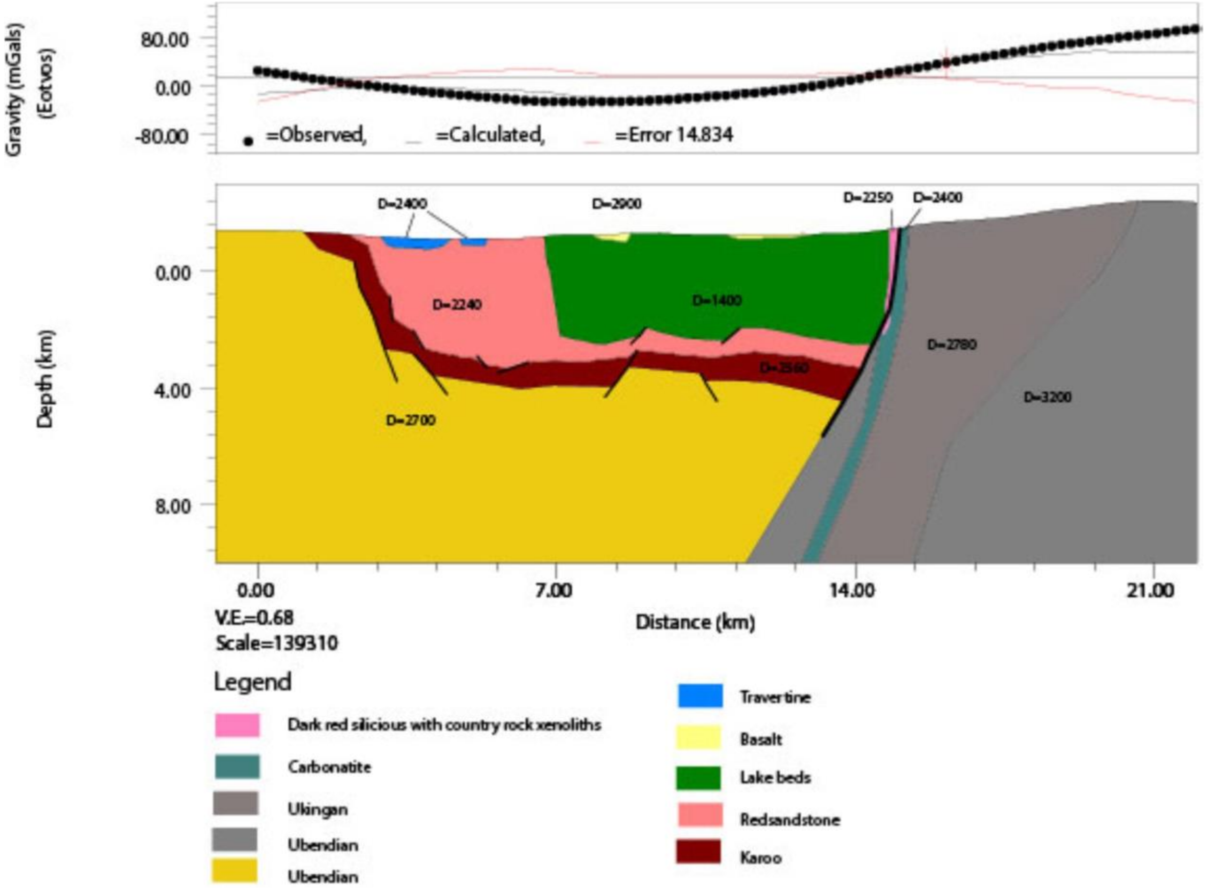


Figure 1. Reconstructed Songwe Model showing the constrained deep structure

Point at depth (Km)	**Temperature** (One Rock Layer Model)	**Temperature** (Two Rock Layers Model)	**Temperature** (All Rock Layers Model)
4.4	340.18 °C	369.26 °C	391.82 °C
5.4	404.10 °C	440.01 °C	454.55 °C

Figure 2. Temperature comparison taken at the same points for all three scenarios.

The study will also incorporate the mechanical and physical parameters from the laboratory measurements and construct a geothermal model that will help in understanding and predicting the long-term geothermal production in Songwe through testing different production scenarios to identify the related impacting factors on fluid flow and thermal production.

Young researcher:

VICTOR GERALD NZEWUJI (MASTER STUDENT AT UNIVERSITY OF MISKOLC - HUNGARY)

System Dynamics Modeling of the Combined Heat Power and Metal extraction (CHPM) concept

Geothermal systems produce a large volume of brine for power generation. Since these brines are the product of long-term water-rock interactions at elevated temperatures at depth, they contain dissolved chemical components including metals at various concentrations. Despite the low concentrations for many dissolved minerals, significant quantities of select minerals could be recovered due to the large volumes of brine utilized by geothermal power plants.

CHPM2030 (Combined Heat, Power and Metal extraction) is a H2020 project funded by the European Union and working on a unique disruptive technology that will combine geothermal energy development and minerals extraction. In the envisioned CHPM technology, an enhanced geothermal system would be established in a deep metal bearing geological formation, which would be conducted in a way that the co-production of energy and metals could be possible.

The main objective of this dissertation is to assess how sensitive the outputs of the components are affected by the variabilities in the key parameters focusing on energy balance using the Landau brine as a case study. Brine properties consisted of about 32 input parameters namely; wellhead temperature (°C), pressure (bar), pH, salinity (g/L), flow rate (L/s), electrode potential (mV) as well as concentrated suspended solids (mg/L) in the brine. These parameters are iterated over through a CHPM system model consisting component models of the CHPM plant, developed by the CHPM project partners. The iteration was done using a Monte Carlo simulation model, also developed by the CHPM project partners. Therefore, the analysis is conducted based on the dataset generated from the simulation.

Two kinds of analysis are conducted in this dissertation. First, a sensitivity analysis of the energy usages and production of the four surface components of the CHPM using key input parameters. This was done using regression method, which is a convenient way of multi-variate analysis. The surface components are the electrolytic metal recovery unit (E3), CHP (E4), gas diffusion electroprecipitation and electro-crystallization (E5) and the salt gradient power unit (E6).

Second, a scenario analysis of the CHP output using two different district heating system connections and two ranges of flow rate. All analysis was performed using the dataset and implemented in Python using Jupyter notebooks and Spyder IDE.

Outputs from the E4 and E6 were found to be sensitive to changes in mass flow rate of the geothermal fluid, temperature and salinity. Increasing flow rate and temperature resulted in increase in electric power generation in the E4, while increasing salinity and flow rate yielded increase the electric power output in the E6. Regression results for the E3 and E5 components using key parameters showed little relationship between the dependent and independent variables. It is possible that the variability in the E3 and E5 possess a non-linear relationship with the key parameters and could also be dependent on other parameters that were not considered in the regression analysis.

From the scenario analysis, it is found that scenario 3 (Low temperature DH 60/40 connection and high flow rate of 100 – 200L/s) produced the most electric power and met the $5MW_{th}$, $10MW_{th}$ and $20MW_{th}$ heat demands as compared to the other scenarios. The scenario 3 produced $9.05MW_e$ and $5MW_{th}$ for a $5MW_{th}$ heat demand, $8.92MW_e$ and $10MW_{th}$ for a $10MW_{th}$ heat demand; and $8.91MW_e$ and $19MW_{th}$ for a $20MW_{th}$ heat demand.

Young researcher:

MUHAMMAD ANEES (PHD STUDENT AT UNIVERSITY OF SZEGED - HUNGARY)

Evaluation of Granites in Gilgit-Baltistan (Pakistan) as Potential Geothermal Prospects

Geothermal manifestations in the northern areas of Pakistan occur in the form of several hot springs which are located along the Indian-Eurasian zone towards the western part of Himalayan Geothermal Belt. It has been hypothesized that heat producing granites in this geothermal belt could be a promising source for the geothermal systems found in this belt. This study aims to apply cost effective remote sensing techniques, gamma-ray spectrometry and ground-based surveys for the evaluation of the radioactive granites (as potential geothermal targets) in the northern areas of Pakistan. The study will employ remote sensing datasets to calculate land surface temperatures and surface emissivity maps from thermal infrared satellite imagery. Visible and short-wave infrared satellite imagery will be used for alteration identification and classification along with lithological mapping. Ground surveys using soil temperature probes will be carried for validation of remote sensing results. Portable gamma-ray spectrometery will be used to measure concentration of radioactive elements in the area and to calculate radiogenic heat production. Rock samples will be collected from areas with high radioactivity and hydrothermal alterations for lab analysis using gamma spectrometry and X-ray Diffraction, respectively. The results of this study will make a significant contribution towards demarcation of potential geothermal zones for further detailed exploration and feasibility studies. The proposed novel methodology is an essential step leading towards cost and time effective geothermal exploration at reconnaissance level.

Young researcher:

GEMMA MITJANAS (PHD STUDENT AT UNIVERSITAT DE BARCELONA - SPAIN)

The Vallès basin Geothermal system in the frame of the GEO-URBAN project

Keywords: Geophysics, fractured bedrock, geothermal, Vallès basin

The GEO-URBAN project aims to explore the potential for low enthalpy geothermal resources in urban environments. In the frame of GEO-URBAN project, two low-enthalpy deep geothermal reservoirs, Dublin basin (Ireland) and Vallès basin (Spain), will be evaluated using geophysical exploration techniques.

In the Vallès basin area (Catalan Coastal Ranges, NE Spain) the thermal anomaly is located in the northeastern limit of the basin, where a highly fractured Hercynian granodiorite acts as the geothermal reservoir. Nevertheless, the geological structure of this area, as well as the role of the Vallès major normal fault, is poorly understood.

The Vallès geothermal system is located in the Catalan Coastal Ranges (NE Spain). The Catalan

Coastal Ranges display a well-developed horst and graben structure limited by NE-SW and ENEWSW striking normal faults developed during the opening of the Valencia Trough (northwestern Mediterranean). The Vallès-Penedès belongs to the outermost graben of this extensional system. Its internal structure is characterized by the presence of longitudinal (ENE– WSW) faults that compartmentalize a NW - tilted block (Roca et al. 1999). The hot springs studied are located at the NW edge of this basin close to the main bounding fault (the Vallès normal Fault) (Figure 1).

The major structure of the study area is the Vallès-Penedès fault. Some of the few available seismic profiles of previous studies show roll-over geometry in the hanging-wall (Miocene), what suggested a listric fault geometry (Sàbat et al., 1997; Roca et al., 1999), with the detachment depth of the faults located in the lower/upper crust boundary (13-15 km) (Bartrina et al., 1992; Roca and Guimerà, 1992). All these authors including other works as Gaspar-Escribano et al., (2004) or Santanach et al., (2011) identified the major thickness of the Miocene deposits next to the fault.

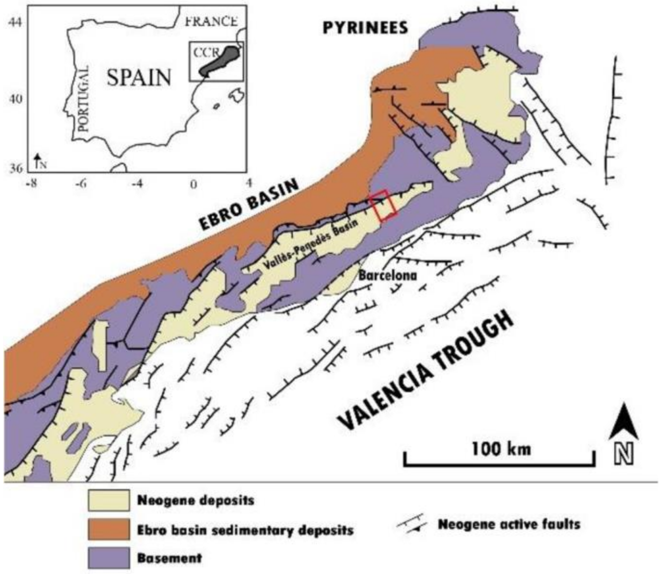


Figure 1. Structural map of the Valencia trough (mod. From Roca & Desegaulx, 1992).

Different geological and geophysical surveys made in the 80s determined the presence of geothermal anomalies in different parts of the Vallès basin, although their resources were not exploited. In our study, we decided to focus on La Garriga-Samalús area (northeastern edge of the basin), where the fractured nature of the granite bedrock represents a geological challenge.

Several geophysical techniques are being applied in this area to understand the main structure, which seems to control the heat and the hot-water flow. Magnetotellurics (MT), Gravity, Electrical resistivity tomography (ERT), passive seismic (H/V) and control source electromagnetics (CSEM), have already been tried, however, the models are not yet completed.

Although the geophysical study makes up most of the study, we are also improving the geological map of the area, making a fractures study at different scales. We are working with DEM alignments analysis, and fractures study from outcrops and thin sections.

The geological model will be built up using all the geophysical information, the surface data, and previous information, as six exploratory wells made by the Geological Survey of Spain (IGME, 1984). Moreover, it will include petrophysical data from the granodiorite rock, which would help us to correlate the geophysical results and the geology of the area, also being essential for the final flow model.

Our preliminary results in gravity show a strong gravity gradient in the NE-SW Vallès half-graben system and the recent MT profiles image the main fault of that system (Vallès normal fault). Moreover, our results disagree with the previous conceptual model of the basin geometry. All the previous studies assumed the roll-over geometry detected in the center of the basin. Therefore, to create a new geological model, we are considering an extended area for the geophysical study.

Interpretations of the fractures study, together with geophysical data and models, have allowed the characterization of damage zones associated with the fault system which are directly related to the fluid flow and the hot springs. The nature of these damage zones could be related to relay ramps, commonly regarded as efficient conduits for fluid flow.

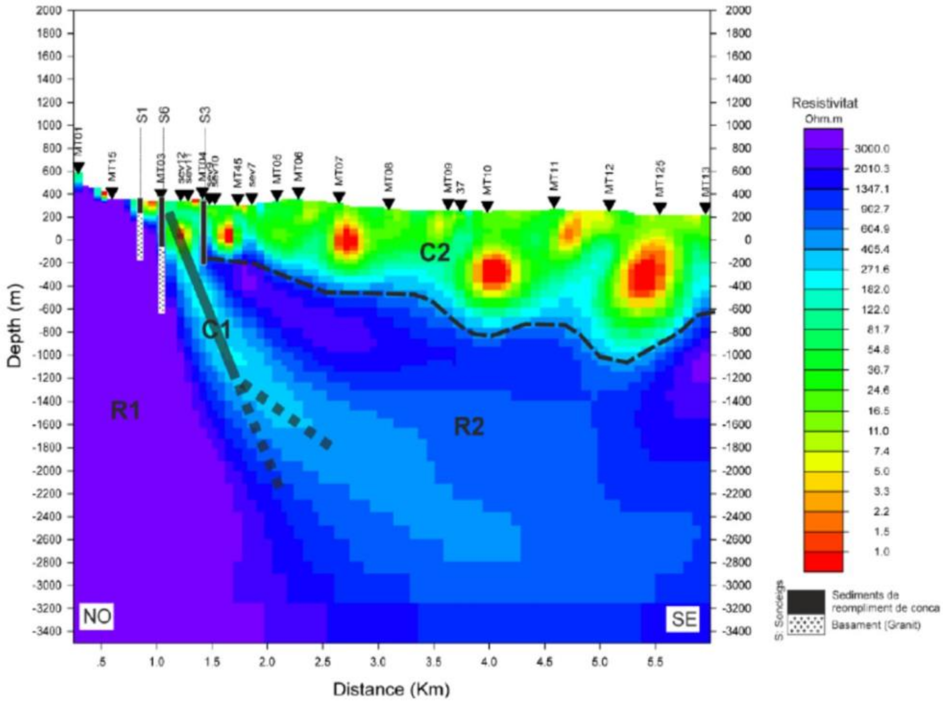


Figure 2. Magnetotelluric profile from the Montseny massif towards the depocenter of the Vallès basin.

Friday 20th: Excursions cancelled

List of attendees (students/fellows)

FIRST NAME	SURNAME	STATUS	INSTITUTION
Azouaou	**Acheraiou**	Master student	CY Cergy Paris Université
Fariza	**Aissani**	Master student	CY Cergy Paris Université
Abdelkader	**Aït Ouali**	Senior scientist	CDER (Alg. Ren. En. Research Center)
Muhammad	**Anees**	PhD candidate	Georg-August Universität Göttingen
Rhadityo	**Arbarim**	PhD candidate	Technische Universität Darmstadt
Cédric	**Bailly**	Post-doc	CY Cergy Paris Université
Sarah	**Boudriga**	Master student	CY Cergy Paris Université
Adam	**Cherchali**	Master student	CY Cergy Paris Université
Hugo	**Chirol**	Master student	UniLasalle Beauvais
Thibaud	**Delphin**	Master student	UniLasalle Beauvais
Mamadou	**Diawara**	Master student	CY Cergy Paris Université
Sara	**Emili**	Master student	Università Roma Tre
Anvar	**Farkhutdinov**	Junior scientist	Bashir State University
Marc	**Fleury**	Senior scientist	IFPEN
Katherine	**Ford**	PhD candidate	Georg-August Universität Göttingen
Floriane	**Forgeot**	Master student	CY Cergy Paris Université
Juliette	**Genoulaz**	Master student	UniLasalle Beauvais
Jules	**Grellier**	Master student	UniLasalle Beauvais
Mathilde	**Haemmerlein**	Master student	UniLasalle Beauvais
Roman	**Hepp**	Master student	Georg-August Universität Göttingen
Valentine	**Jacob**	Master student	CY Cergy Paris Université
Johanne	**Klee**	PhD candidate	UniLasalle Beauvais
Tom	**Kubiak**	Master student	UniLasalle Beauvais
Alexis	**Lavigne**	Master student	CY Cergy Paris Université
Bruno	**Lemaire**	Master student	UniLasalle Beauvais
Baptiste	**Lepillier**	PhD candidate	Delft University of Technology
Ulysse	**Loridant**	Master student	UniLasalle Beauvais
Guillaume	**Marcade**	Master student	UniLasalle Beauvais
Clément	**Mathieu**	Master student	CY Cergy Paris Université
Gemma	**Mitjanas**	PhD candidate	Universitat de Barcelona
Estelle	**Moussion**	Master student	UniLasalle Beauvais
Martha	**Nnko**	PhD candidate	Delft University of Technology
Victor Gerald	**Nzewuji**	Master student	University of Miskolc
Máté	**Osvald**	PhD candidate	University of Szeged
Lorenzo	**Paris**	Master student	Università Roma Tre
Marc	**Perret**	PhD candidate	Université de Genève / IFPEN
Léa	**Perrochet**	PhD candidate	Université de Neufchâtel
Armand	**Pomart**	Master student	UniLasalle Beauvais
Ines	**Raies**	PhD candidate	CY Cergy Paris Université / IFPEN
Julien	**Sauvage**	Master student	UniLasalle Beauvais

Mouniratoun	**Savadogo**	Master student	CY Cergy Paris Université
Katja	**Schulz**	Master student	Technische Universität Darmstadt
Ahmad	**Shahin**	Master student	CY Cergy Paris Université
Anna	**Sustrate**	Master student	Georg-August Universität Göttingen
Renaud	**Toullec**	Senior scientist	UniLasalle Beauvais
Gonzalo Agustin	**Trejo**	Master student	UniLasalle Beauvais
Aysegul	**Turan**	PhD candidate	Technische Universität Darmstadt
Amanda	**Vergara**	PhD candidate	Università Roma Tre / IFPEN
Marc-Aurèle	**Wynants**	Junior scientist	Geological Survey of Belgium
TOTAL COUNT	**49**		**13**

ANNEX 2: FLYER AND POSTER

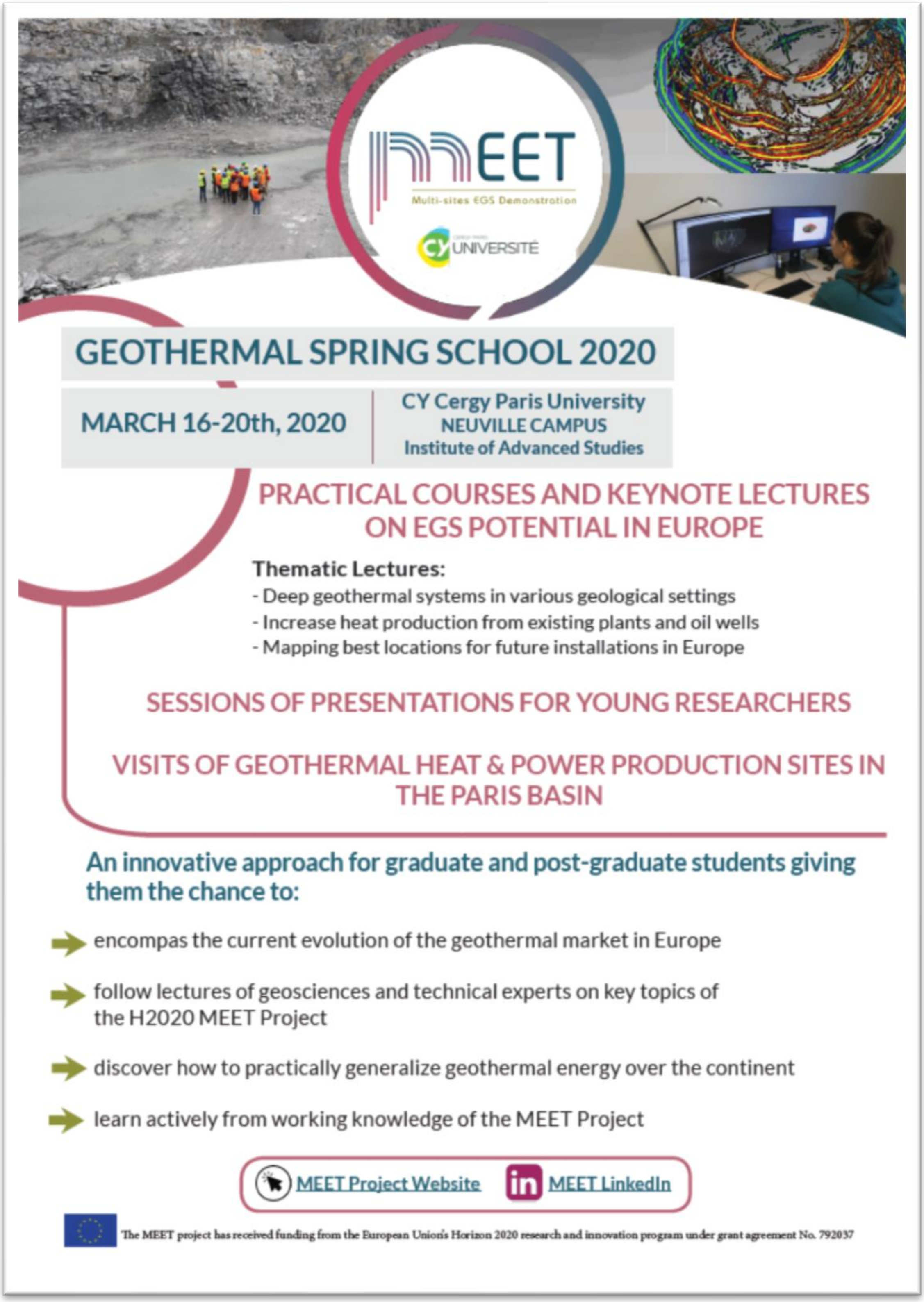


Figure 4: Flyer of the MEET Geothermal Spring School 2020

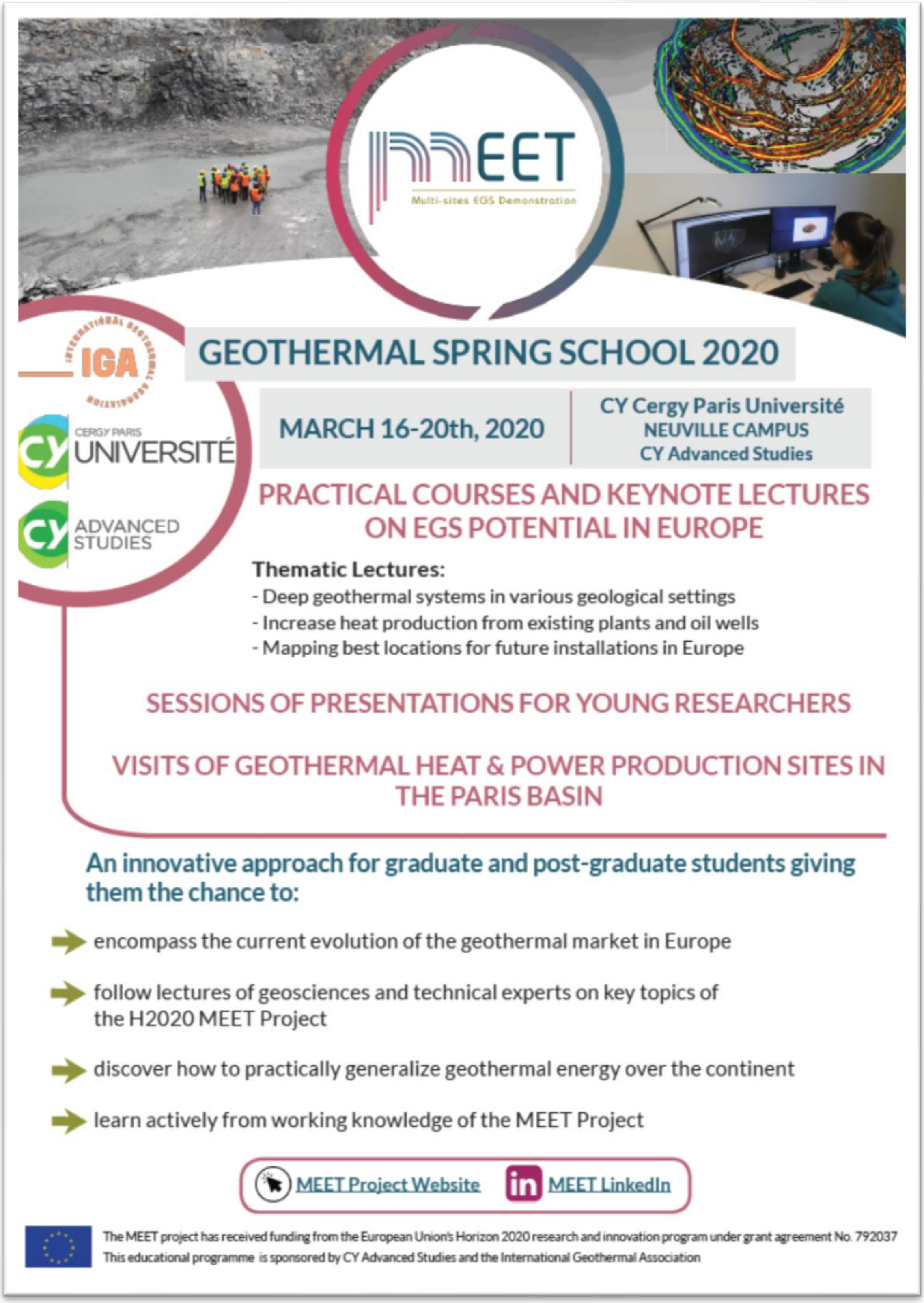


Figure 5: Poster of the MEET Geothermal Spring School, with logos of supporting partners

ANNEX 3: SCHEDULE OF THE SITE VISITS (20TH OF MARCH, 2020)

Sites	Bus 1		Bus 2	
	Arrival	Departure	Arrival	Departure
Departure: CY Cergy Paris Université – Neuville site 1, rue Descartes - 95000 Neuville-sur-Oise		7:30 AM		7:30 AM
Site 1: Geothermal heat plant « Melun l'Almont » (DALKIA operator), 38 Boulevard de Maincy, 77000 Melun	9:30 AM	11:00 AM	2:00 PM	3:30 PM
Site 2: MEET ORC test device (Vermilion Emeraude - MEET partner), Les Noués, CD 215, 77720 Saint-Méry	11:30 AM	1:00 PM	4:00 PM	5:30 PM
Site 3: Geothermal heat plant « Le Mée-sur-Seine » (IDEX operator), Allée du Bois, 77350 Le Mée-sur-Seine	2:00 PM	3:30 PM	9:30 AM	11:00 AM
Site 4: Geothermal heat plant « Dammarie-les-Lys » (ENGIE-Réseaux operator), 1 rue du Port, 77190 Dammarie-les-Lys	4:00 PM	5:30 PM	11:30 AM	1:00 PM
Drop at Porte de Clignancourt (north of Paris)	7:00 PM	7:15 PM	7:00 PM	7:15 PM
Return: CY Cergy Paris Université – Neuville site 1, rue Descartes - 95000 Neuville-sur-Oise	8:00 PM		8:00 PM	

Imprint

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Report Authorship	SENGELEN X. and LEDESERT B., (2020). First geothermal week school organisation, MEET report, Deliverable D8.6, April 2020, 63 pp.
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