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Conference Program

08:30	Welcome - Registration		
09:00	KEYNOTE 1	**Alexandra Kushnir** IPGS	Volcanica: A Community-based Initiative Towards Diamond Open Access in Volcanology
09:30	SESSION 1 *Alteration and fractures*	**Glass Carole** IPGS	Hydrothermal alteration in the new deep geothermal well GIL-1 (Illkirch, France)
09:45		**Köpke Rike** IPGS	Characterization of the Rittershoffen Deep Geothermal Reservoir by seismic monitoring
10:00		**Vincent-Dospital Tom** IPGS	Peeling dynamics and triboluminescence: a thermal model for the rupture of adhesives
10:15	Coffee break		
10:45	SESSION 2 *Geoscience methods and tools*	**Chaffaut Quentin** IPGS	Hybrid gravimetry as a tool to spatialize water storage fluctuations in mountainous catchments. The case of the Strengbach catchment, Vosges mountains, France
11:00		**Desrues Mathilde** IPGS	TSM—Tracing Surface Motion: A Generic Toolbox for Analyzing Ground-Based Image Time Series of Slope Deformation
11:15		**Renouard Alexandra** IPGS	Contribution of machine learning to earthquake detection in high anthropogenic context
11:30	SESSION 3 *Rifted margins, different approaches*	**Miró Jordi** IPGS	Analogue modeling to test the reactivation of transfer systems: the case of the Santander Transfer System (Bay of Biscay – Pyrenean realm)
11:45		**Chao Peng** IPGS	The stratigraphic tape recorder of crustal thinning and breakup: insights from the NW SCS
12:00		**Bernard Paul** IPGS	Potential field methods applied to the quantification of the magnetization of the oceanic lithosphere
12:15	Lunch Break - Poster Session		

14:15	KEYNOTE 2	**Welter Richard** LHyGeS	De la cristallographie à la géochimie : exemple d'un parcours pluridisciplinaire en chimie
14:45	SESSION 4 *Hydrogeological and geochemical modeling*	**Droz Boris** LHyGeS	Pesticides dissipation in river at the sediment-water interface: insights from Compound Specific Isotope Analysis (CSIA)
15:00		**Drouin Guillaume** LHyGeS	Pesticide dissipation at the sediment-water interface: coupling modelling and compound specific isotope analysis
15:15		**Rambourg Dimitri** LHyGeS	Using holes to know it all: from point data to a 3D aquifer model
15:30		**Koohbor Behshad** LHyGeS	An efficient Discrete Fracture-Matrix model for flow in variably-saturated fractured porous media
15:45	Coffee break		
16:00	Best Presentation and Poster Election		

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SESSION 1: Alteration and fractures

S1.1: Hydrothermal alteration in the new deep geothermal well GIL-1 (Illkirch, France)

Carole Glaas[1,2], Patricia Patrier[3], Jeanne Vidal[1,4], Daniel Beaufort[3], Jean-François Girard[2], Albert Genter[1]

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The network of natural fractures in the granitic basement of the Upper Rhine Graben (URG) is the seat of intense fluid circulations. Fluid circulations lead to mineralizations depending on the temperature (160-170°C), pressure and salinity (100g/L), but also directly linked to the residual permeability of the fracture network. Hence, the preliminary identification of the mineralogical phases present in the first geothermal well of Illkirch located South of Strasbourg (France) is crucial. This new geothermal well (GIL-1), has been drilled to 3.8 km deep in a granitic basement. Drill cuttings and geophysical logs from basement were investigated in terms of hydrothermal alteration and natural fractures respectively. Petrographic observations of the 250 cuttings samples between 2900 and 3800 m MD were conducted on-site during the drilling with binocular loupe and enabled to identify the hydrothermal alteration grades in the open-hole granitic section of the well. From binocular examination, secondary minerals like drusy quartz, carbonates and anhydrite were spatially correlated to the occurrences of natural fractures. In the granitic section corresponding to propylitic alteration, phyllosilicates include primary biotite, muscovite and secondary chlorite. Then, 48 cuttings samples were analyzed by X- ray diffraction (XRD) to identify the secondary clay mineralogy corresponding to poorly crystallized illite (PCI) and illite-rich illite-smectite mixed layers (I/S ML) which generally takes place within fractured zones (FZs). Mud logging and geophysical logs acquired in the granitic section of GIL-1 well have been used for characterizing fracture location (calcimetry, temperature log) and fracture orientation (electrical image logs). The granitic section of the well is characterized by a dense network of natural fractures: about 1200 electrically conductive or resistive fractures have been observed on the image logs. From temperature logs, several permeable zones have been identified and correlated with the occurrences of natural conductive fractures. From 2900 to 3100 m MD, the clay signature is mainly governed by the occurrences of PCI and I/S ML which are correlated to permeable FZs. In the deepest part of the granitic section, secondary chlorite and possible secondary well crystallized illite (WCI) have been observed, corresponding to the cooling of the granitic pluton. These secondary minerals observed in the GIL-1 well are identical than the secondary minerals observed in the wells of the geothermal projects exploited for heat and electricity production in Northern Alsace.

Keywords: illite, clay minerals, fracture zone, granitic reservoir, X-ray diffraction (XRD), Short Wave Infrared (SWIR), Illkirch, Upper Rhine Graben (URG)

S1.2: Characterization of the Rittershoffen Deep Geothermal Reservoir by seismic monitoring

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In a geothermal reservoir, seismicity may be induced due to pressure changes in the underground as a result of drilling, stimulation or circulation operations. The induced seismic events are therefore strongly linked to the fluid flow and the geological structures that make this fluid flow possible. The development of the deep geothermal site at Rittershoffen (Alsace, France) was monitored continuously by different seismic networks covering various operational periods from September 2012 to October 2014, including the drilling of the well doublet GRT1/GRT2 and stimulation of GRT1. The seismicity induced by these operations has the potential to give valuable insight into the geomechanical behaviour of the reservoir and the geometry of the underground fracture network. This work gives an overview of the spatial and temporal development of the induced seismicity and the magnitudes of the events to give first insight into active structures in the reservoir.
To obtain a robust database for this analysis, we first apply a template matching code to the continuous waveforms recorded by the seismic networks. This technique is based on the calculation of the correlation coefficient between continuous and template waveforms. It outperforms conventional STA/LTA detectors in terms of sensitivity to events with low signal-to-noise ratio and picking consistency for events with waveforms similar to the templates. After running the detection with the template matching code, the relative locations of all detected events are calculated with the software HypoDD. The visualization of the spatial and temporal evolution of the events and their magnitudes shows, how the different operations influence the seismogenic development of the reservoir. The structures, which are activated during the different processes are highlighted, showing the fault network in the reservoir.

S1.3: Peeling dynamics and triboluminescence : a thermal model for the rupture of adhesives

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The dynamics for unrolling adhesive tape, such as the fracture dynamics of many materials [1], displays various regimes [2]. At low mechanical load, the rupture front creeps with a low velocity (i.e., centimeters per second and less), and its propagation is often considered as sub-critical. At higher loads, however, the fronts reach a far quicker regime, with velocities similar to that of the mechanical waves in the tape glue. In between these two propagation modes, an hysteresis situation holds, that implies some stick-slip in the peeling of tape.

To describe all of these phenomena, we propose a simple model, only based on statistical physics, as understood by an Arrhenius law, and on the dissipation and diffusion of heat around the rupture front. Such a model successfully accounts for all propagation velocities, measured over seven orders of magnitude as a function of the energy release rate (i.e., the intensity of the mechanical input that is transmitted to the front). In this new description of fracture dynamics, the transition from slow creep to fast peeling is obtained when the front temperature significantly exceed the one of the ambient thermal bath. The adhesion of a particular glue could hence depends on its thermal properties, such as its heat conductivity and capacity.

To explain peeling speeds close to the Rayleigh waves velocity, we predict that the adhesive temperature can approach tens of thousands Kelvin, over the scale of a few hundreds nanometers around the rupture front. While it is possible to measure infrared emissions, when unrolling tape as when breaking other materials [3], matter at such temperature should rather emit in the visible spectrum and the ultra-violet domain. Thus, our model explains the triboluminescence phenomena (i.e., the emission of visible light during the propagation of fractures), notably observed in glass [4], quartz, but also in the pressure sensitive adhesive of standard roller tapes.

References

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[3] Toussaint et al., Soft Matter, 2016.
[4] Pallares et al., Europhysics Letters, 2012

SESSION 2: Geosciences methods and tools

S2.1: Hybrid gravimetry as a tool to spatialize water storage fluctuations in mountainous catchments. The case of the Strengbach catchment, Vosges mountains, France.

Quentin Chaffaut[1], Jacques Hinderer[1], Frédéric Masson[1], Jean-Daniel Bernard[1], Daniel Viville[2], Marie-Claire Pierret[2], Nolwenn Lesparre[2], Solenn Cotel[2], Benjamin Jeannot[3]

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Due to their strong topography, the hydrological functioning of mountainous catchments is still a challenge to be assessed. Nevertheless, water resource management is a key issue in mountainous areas, especially in the context of climate change.

The spatial-integrative nature of gravimetric measurements makes them sensitive to waterstorage fluctuations around the observation points. Thus, gravimetry is a key method to investigate water storage fluctuations at middle scale.

At the Strengbach catchment in the Vosges mountains (France) continuous monitoring of gravity fluctuations is provided by a superconducting gravimeter iGrav#30 since June 2017. In addition, the continuous monitoring of meteo-hydrological fluxes allows to compute the hydrological budget of the catchment. As a first step, we distributed the corresponding amount of water along a single layer covering the surface topography and computed the associated gravity response, which shows strong agreement with iGrav#30 observed gravity hence proving that gravity is a good proxy of space-averaged water storage fluctuations.

In a next step we choose to distribute water using the low dimensional hydrological model NIHM (Normally Integrated Hydrological Model, Jeannot et al., 2018). NIHM reproduces the outflow measured at the catchment outlet but remains poorly constrained in terms of water storage spatialization due to the lack of reliable piezometric observations. One of our objectives is to calibrate NIHM using hybrid gravimetry where relative gravity measurements are done in repeated surveys on a network of stations using the superconducting gravimeter as reference station.

The gravity response of NIHM is computed for the entire catchment and is compared with the observed gravity map resulting from our hybrid gravity approach.

S2.2: TSM—Tracing Surface Motion: A Generic Toolbox for Analyzing Ground-Based Image Time Series of Slope Deformation

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Passive sensors such as multi-spectral (e.g., Single Lens Reflex, SLR) cameras are increasingly being used for geohazards monitoring (landslides, cliffs affected by rock falls, ice glaciers, and volcano flanks) because of their low cost compared to expensive terrestrial laser scanner (TLS) or radar imaging (GB- InSAR) systems. Indeed, due to the large consumer market, sensor resolution and quality (e.g., gain, dynamic range, and geometry) are increasing rapidly. For gravitational processes, such as landslides, recent research has focused on the development and implementation of image correlation techniques to estimate the spatial shift between at least a pair of images by maximizing a cross-correlation function. A generic and fully automated pipeline is proposed for the processing of long image time series acquired for several site configurations. The system associates modules for 1) the selection of the image sequences, 2) the registration of the image stacks and the correction of the camera movements, and 3) the calculation of the terrain motion using change detection approaches. The system is based on the open-source photogrammetric library MicMac and tailored for the processing of monoscopic images. A sensitivity analysis is conducted to design and test the image processing for two use cases respectively the Chambon landslide (Isère, France) characterized by slow motion (< 10 cm.day−1), and the Pas de l'Ours landslide (Hautes-Alpes, France) characterized by moderate motion (> 50 cm.day−1). Four categories of parameters are tested: the image modality, the image matching parameters, the size of the stable area used in the co-registration stage, and the strategy used to combine the images in the time series. The application of the pipeline on the two use cases provides information about the kinematics and the spatial behavior of the landslides.

SESSION 2: Geosciences methods and tools

S2.3: Contribution of machine learning to earthquake detection in high anthropogenic context

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Seismic catalogs are seismologists' inherently incomplete tools. Because of uneven station distribution or environmental noise level, completeness magnitude vary over space and time and natural as well as anthropogenic events are often poorly discriminated. The degree of missingness affects how we characterize the seismic behavior of seismogenic areas, how we analyze the statistical power of seismic patterns, how we estimate seismic hazard models, and how we investigate what triggers and drives the seismicity.

One of the opportunities to improve seismic monitoring by increasing the number of events we detect and correctly discriminate involves taking advantage of recent advances in data-processing techniques. In the northwestern European Rhine area, the regional network of seismic stations has greatly expanded over recent years. This new network inspired us to improve the existing automated system that detects and locates both microseismicity and moderate magnitude seismicity in the area. The high anthropogenic context of this region (quarry blasting, mining, geothermal exploitation), means that improving detection and location is not enough: we also need to improve discrimination of anthropogenic events.

We developed a fully automatic detection procedure with robust discrimination within SeisComP3. Adapted to low detection thresholds and large datasets, it is designed for High Performance Computing but can be incorporated into real-time routine processing. We improved the SeisComp3 standard protocol for event creation by fine-tuning it, and creating new SeisComp3 modules. The first module enhances the SeisComP3 selection procedure of the best origin for each event. The second one integrates machine learning tools to classify events and label them as either false alarms, earthquakes, or quarry blasts. The discrimination is carried out by a Random Forest algorithm trained on a pre-discriminated dataset (vectors of 400 features extracted for each event).

Keywords: machine learning, earthquake detection, seismological observatories, small magnitudes

SESSION 3: Rifted margins, different approaches

S3.1: Analogue modeling to test the reactivation of transfer systems: the case of the Santander Transfer System (Bay of Biscay – Pyrenean realm)

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The Bay of Biscay – Pyrenean system corresponds to a Mesozoic (160 to 84 Ma) rift system that was subsequently reactivated during Late Cretaceous to Cenozoic (84 to 23 Ma) time leading to the formation of the Pyrenean orogen along the Iberian-European plate boundary. The structure of former rift domains and its role during subsequent compressional reactivation has been extensively studied over the past years. Nevertheless, the investigations concerning the segmentation of the Bay of Biscay – Pyrenean system (e.g. Santander Transfer System and Pamplona fault) are still in an embryonic stage of knowledge despite the important amount of available data. Thus, the Pyrenees are a perfect natural laboratory to study such transfer zones.

The architecture of transfer zones separating segmented fault systems are mainly controlled by extensional/contractional rates, changes in stress direction, lateral variations in rheology and inheritance.Transfer systems can develop in extensional settings as well as in contractional or inverted systems (e.g. Bay of Biscay – Pyrenean system) and in both oceanic and continental domains. However, few studies have addressed the rift segmentation (transfer zones) and its role during the inversion leading to structural variability during the development of mountain belts.

At the scale of the Bay of Biscay – Pyrenean system, the Santander Transfer System represents a key area to unravel the evolution and the linkage between the former Bay of Biscay and the Pyrenean rift systems. In our study, we use an experimental approach (sandbox models) to model the Santander Transfer System with the aim to determine the role of (I) the inherited basement structures, (II) the presence of an effectively pre-rift decoupling level, and (III) the implications of the lateral termination of this decoupling level during extension and reactivation of the transfer system. Our results emphasize that the Triassic extensional fault system as well as the distribution of the Upper Triassic evaporites played a major role during the segmentation of the Late Jurassic-Early Cretaceous rift system as well as during the subsequent inversion. This study is developed as part of the OROGEN project and uses the GEOMODELS Analog Modelling Laboratory.

Keywords: Santander Transfer System, Bay of Biscay, Pyrenees, segmentation, rift-inheritance, analogue models

S3.2: The stratigraphic tape recorder of crustal thinning and breakup: insights from the NW SCS

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In the last two decades, knowledge of the South China Sea (SCS) rifted margin has significantly evolved as the International Ocean Discovery Program (IODP) drilling and hydrocarbon explorations. Due to the limited seismic data, lack of drilling, it is yet unclear how to define the upper-, lower-plate margins, to determine the tectono-sedimentary-magmatic evolution, deformation mechanisms and isostatic response during crustal thinning and break up at the North West South China Sea (NW SCS). This study is based on the observation of the architecture across a conjugate margin through the NW SCS image by a reflection seismic section. The aim is to understand the evolution of deformation processes in 2D and to analyse the evolution of deformation modes through time and space by linking the tectono-stratigraphic evolution with the observed crustal thinning and breakup. Our work provides a detailed description of the NW SCS crustal architecture, determines the tectono-sedimentary evolution, define the extensional domains, margin architecture and quantify the amount of strain. Moreover, we aim to characterize distinctive stratal and crustal architectures to propose qualitative and quantitative criteria to identify and interpret the conjugate rifted margin evolution.

Keywords: Tectono-sedimentary-magmatic evolution; rifting; NW SCS margins

SESSION 3: Rifted margins, different approaches

S3.3: Potential field methods applied to the quantification of the magnetization of the oceanic lithosphere

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The most commonly used method to determine the age of the oceanic crust consists in a qualitative study of the magnetic anomalies. The aim of this thesis is to apply quantitative methods to interpret marine magnetic anomalies, and more specifically to determine in an objective way the positions of Earth's magnetic field reversals, and so their age. This point is particularly interesting in order to understand magma-poor rifted margins, where the interpretation of the magnetic anomalies is debated (application to the Australian-Antarctica and Iberia-Newfoundland conjugate margins). Indeed, several anomalies may be linked to other process such as lithospheric break-up. This process is characterized by magmatic events which can lead to magnetic lineations without clear link to the Earth's magnetic field reversals.

The results of the thesis are focused on the Australia-Antarctica conjugate margins. The first step has been the joint comparison of a transformed magnetic anomaly formerly interpreted as the isochrone C34 with the gravity anomaly and the seismic profiles of the AG199, AG228 and AG229 on a regional scale then has been realized. This comparison allows us to correlate the regional magnetic and gravity anomalies with the structural limit between the highly-extended crust and mantle exhumation domains on the Antarctic margin. This work has been followed by a forward modelling of magnetic and gravimetric anomalies constrained by the seismic interpretation on both margins. The main results of this modelling is that the magnetic anomalies of the mantle exhumation domain can be coherently modelled without involving Earth's magnetic field reversals.

Keywords: magma-poor rifted margins; rifting; oceanization; mantle exhumation; magnetic anomalies

SESSION 4: Hydrogeological and geochemical modelling

S4.1: Pesticides dissipation in river at the sediment-water interface: insights from Compound Specific Isotope Analysis (CSIA)

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The widespread occurrence of pesticides in the environment jeopardizes the human water security and river ecosystem. Despite several decades of pesticide research, knowledge on the extent and dynamics of pesticide dissipation at the catchment scale including processes in the river network is currently limited. In contrast to concentration-based approaches, Compound Specific Isotope Analysis (CSIA) allows to evaluate the contribution of in situ pesticide degradation with regard to other non-degradative processes. By combining both approach (i.e., concentration and CSIA), this thesis aims to understand the dynamic of pesticide transformation in river ecosystems and in particular at the sediment-water interface (SWI).

Effective methods were developed to extract legacy and currently applied pesticides (Atrazine, S-Metolachlor, Terbutryn, Acetochlor and Metalaxyl) from water and sediment at the SWI interface with a high recovery (> 80%) and without any isotope fractionation ($\Delta\delta^{13}C > |0.5‰|$). These methods were then applied for closed batch experiments in the laboratory to investigate biodegradation pathways and kinetics of pesticides under oxic and anoxic conditions. Carbon and nitrogen isotope enrichment factors (εC and εN lab) were retrieved from closed batch experiments to quantify at the catchment-river scale the biodegradation pathways and the degradation extent.

In addition, conservative and non-conservative tracer experiments were carried out in a 15 cm long river channel to integrate hydrological conditions that control pesticide dynamics at the SWI. Pesticide CSIA was eventually tested in the Souffel catchment (120 km2, Bas-Rhin, France) to assess pesticide dissipation in river. Samples from 3 waste water treatment plants and 11 points from upstream to downstream were collected over an agricultural season (March to October 2019). In addition, the dataset will serve to calibrate a river reactive transport model developed in the PhD project of G. Drouin.

Keywords: degradation pathway; fresh water system, micropolluant

SESSION 4: Hydrogeological and geochemical modelling

S4.2: Pesticide dissipation at the sediment-water interface: coupling modelling and compound specific isotope analysis

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The Sediment-Water Interface (SWI) at the river scale is a dynamic biogeochemical zone of intense reactivity that controls pesticide dissipation. Both transport and destructive processes control pesticides dissipation at the SWI. However, pesticide degradation only occurs through destructive processes involving hydrolysis, photolysis and biodegradation, which may be evaluated with Compound Specific Isotope Analysis (CSIA) of pesticides. Then, predicting pesticide dissipation at the SWI requires to account for interfacial mass exchanges at the SWI for varying water flow as well as for the spatial distribution of main degradation pathways within the SWI. Reactive transport modelling (RTM) coupled with Compound Specific Isotope Analysis (CSIA) may improve understanding of the interplay between pesticide transport and degradation at the SWI. This study addresses the pesticide exchange across the SWI for a representative panel of hydrological conditions as well as mechanistic knowledge on pesticide degradation at the SWI.

Mechanistic characterizations of pesticide degradation at the SWI (i.e. PhD thesis of B. Droz) were combined with conservative and non-conservative tracer experiments within a 15 cm long river model in laboratory to characterize pesticide transport and degradation at the SWI. A two domain transport model, accounting for a pure fluid layer (Navier-Stokes) and a porous medium (Darcy-Brinkmann) is then validated against experimental data. The model is further implemented to incorporate pesticides degradation and isotopic data that correspond to prevailing degradation pathways. Patterns of attenuation potentials examined in the channel model are further tested at river scale (Avenheimerbach, 3 km2, France) over a whole agricultural season (March to October 2020) with the help of CSIA for pesticide sources identification and degradation tracking. Altogether, this proof of concept study will help understanding pesticide fate at river scale for agriculturally impacted catchments.

Keywords: Sediment-water interface; Reactive Transport Modelling; Darcy-Brinkman approach; Compound Specific Isotope Analysis; Agricultural catchment; Pesticides

SESSION 4: Hydrogeological and geochemical modelling

S4.3: Using holes to know it all: from point data to a 3D aquifer model

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The identification of parameter - i.e. specific yield and hydraulic conductivity - over the entirety of an aquifer domain is crucial to properly model groundwater flow and contamination. Most of the time, only discrete data are available, in time and space. Also, direct measurement of those parameters, through pumping tests for example, are very difficult and costly to acquire, especially over large areas. Inversion techniques and geostatistical procedures overcome these limitations, allowing to unravel complex systems heterogeneity with limited data.

Methodologically speaking, head water measurements (piezometers) are used to calibrate parameter fields in 2D, that is, averaged over the vertical. The inversion procedure is regularized thanks to a Zonal Adaptive Multi-Scale Triangulation (ZAMT) where the parameter grid is dissociated from the calculation mesh, able of local refinement and zoned in order to integrate prior geological knowledge about the distribution of heterogeneity. Meanwhile, 3D reservoir geometries are inferred from spatial analysis of borehole geological data, using transition probabilities and Markov Chain processes (T-PROGS, S. Carle, 1999). Each categorical geological data (lithofacies) hydraulic conductivity is then calculated in order to fit best the mean values resulting from the 2D inversion.

The study site is an alluvial (unconfined) aquifer of 7.6 km2, situated in the southern, Mediterranean part of France. The inversion runs with a chronicle of 46 piezometers over 5 years (2012-2017), at a decadal time step, and with a convergence threshold ensuring a mean error less than 20 cm. The spatial analysis for constructing the reservoir geometry relies on 351 boreholes descriptions. T-PROGS interpolation well preserves the global lithofacies proportions and produces good continuity of geological layers, consistent with the deposition pattern expected for an alluvial aquifer.

Keywords: Groundwater; Inverse methods; Geostatistics

SESSION 4: Hydrogeological and geochemical modelling

S4.4: An efficient Discrete Fracture-Matrix model for flow in variably-saturated fractured porous media

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Flow in fractured porous media is encountered in a broad spectrum of environmental, industrial and engineering applications such as management of karstic aquifers, geothermal systems, hydraulic fracturing, carbon dioxide sequestration and oil production. Most of the existing studies in the literature deal with saturated fractured porous media while flow in unsaturated fractured porous media is marginally investigated and the related processes are not fully understood. From a numerical point of view, accurate solution of the variably-saturated flow remains a challenge, especially in the presence of formation fractures and sharp wetting fronts. Fractures typically introduce high complex geometry that requires dense meshing with fine elements to capture the high contrast in properties between the fractures and the adjacent matrix zones.

The Discrete Fracture-Matrix (DFM) model approach, in which the fractures are embedded as lower-dimensional elements, (n-1)-D, in higher-dimensional physical domain, n-D, is widely used to deal with the flow in saturated fractured porous media. To the best of our knowledge, the DFM approach has not been implemented for flow in unsaturated fractured porous media. Thus the first objective of this work is to develop a new efficient model for variably-saturated flow in fractured porous media based on the DFM approach.

In this model, we use Richard's equation for both the matrix and fractures. To address challenges related to spatial discretization, the mixed hybrid finite element method with a new mass-lumping technique is implemented to avoid spurious oscillations. Time integration is performed using an advanced solver based on the method of lines with the privilege of selecting time step sizes within the fractures different from those in the matrix. The newly developed DFM model is verified against an industrial FE-based simulator and showed significant superiority in terms of efficiency and robustness.

Keywords: Discrete Fracture-Matrix model; Variably Saturated Flow; Mixed Hybrid Finite Element method; Mass Lumping; Method of Lines

POSTER SESSION – IPGS

The pre-seismic phase of the 2017 Valparaiso Mw 6.9 earthquake: assessment of aseismic to seismic partitioning with reliable uncertainty estimates

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Transient deformations associated with a suite of foreshocks have recently been observed before large earthquakes at several subduction zones (e.g., Chile and Japan), suggesting the occurrence of a detectable pre-seismic slow slip preceding large seismic ruptures. Documenting accurately this preseismic activity is of key interest for our understanding of faulting processes, as well as for earthquake hazard assessment. In this respect, a critical issue consists in discriminating the respective contributions from seismic and aseismic slip to the total moment released during the pre-seismic phase. We focus on the April-May 2017 Valparaiso earthquake sequence, which involved a Mw=6.9 earthquake preceded by a noticeable foreshock activity. Up to four days before the mainshock, local GPS stations recorded a transient eastward displacement suggesting the occurrence of aseismic slip on the plate interface (Ruiz et al., 2017). To assess the relative contribution of seismic and aseismic slip during this preseismic phase, we compare the surface displacement caused by the foreshocks to the observed GPS transient. With this purpose, we invert for the Centroid Moment Tensor (CMT) parameters of Mw≥3.8 foreshocks. A critical step of this procedure lies in uncertainty estimates as the observed pre-seismic signal is this both short (4 days) and of low amplitude (surface displacement ≤ 10 mm).. This is done using a Bayesian approach accounting for both observational errors and prediction uncertainties due to inaccuracies in the Earth structure assumed to model the waveforms. This methodology, applied to the Valparaiso earthquake sequence, allows us to (1) quantify the amount of surface displacement attributed to the foreshocks, (2) identify a remaining source of surface displacement which originates from the foreshocks area, and (3) postulate that pre-seismic aseismic slip on the subduction interface has a moment magnitude between 6.0 and 6.4, which exceeds the cumulated moment magnitude released by the foreshocks.

POSTER SESSION – IPGS

The mechanical behaviour of porous synthetic rocks

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Experimental rock mechanics studies underpin our understanding of the relationship between microstructural attributes and bulk mechanical properties of natural materials. Considerable progress has been made but intrinsic variability from sample to sample and structural heterogeneity remain limitations to the study of the contribution of each microstructural parameter independently. Synthetic rocks for which these parameters can be predetermined and designed provide the means to circumvent the inherent parameters interdependence and variability of natural rocks. Sintering spherical glass beads has been previously shown to be an effective method to produce quality, reproducible synthetic rock samples. Importantly, this method allows for a tight control on microstructural attributes (e.g., pore and grain size and shape) and porosity. We prepared suites of samples with monodisperse grain size distributions using spherical beads. We systematically measured porosity and gas permeability before running hydrostatic experiments and triaxial deformation tests. These tests were conducted on water-saturated samples, in drained conditions (with a fixed pore pressure of 10 MPa), at room temperature, at a constant strain-rate and at effective pressures ranging from 20 to 190 MPa. The porosity-permeability trend for our synthetic samples is in good agreement with those for porous sandstones. Our hydrostatic curves show a critical effective pressure beyond which most grains are crushed while pore space undergoes a substantial reduction. We observe a strong dependence between the porosity and the critical pressure for grain crushing. We used a combination of triaxial experiments and hydrostatic compression experiments to map out the failure envelopes, the shapes of which are similar to those for porous rocks. Our novel approach allows us to parameterize specifically for the importance of porosity and grain or pore size on the mechanical behaviour of porous materials in general, and move beyond empirical approaches to naturally variable materials.

Keywords: synthetic rock ; sintering ; mechanical behaviour ; microstructure

POSTER SESSION – IPGS

Late Quaternary dynamics of the Laurentide Ice Sheet in Clyde Inlet and its adjacent continental shelf, northeastern Baffin Island (Arctic Canada)

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The maximal extent of the Laurentide Ice Sheet (LIS) on eastern Baffin Island during the Last Glacial Maximum (LGM; about 20 000 years ago) has been widely debated during the last decades as different palaeo-glaciological models have been proposed. Spatial and temporal variability of ice sheets extension during Quaternary glaciations complicate the establishment of a reliable reconstruction of the ice margin. Furthermore, the lack of geophysical data in most of the fjords, and seaward, makes it difficult to reconcile the proposed terrestrial and marine glacial margins. Here we use high-resolution swath bathymetry imagery, combined with acoustic stratigraphy data and sediment cores collected during various oceanographic expeditions, focusing on the ice dynamics in the area of Clyde Inlet since the LGM. Our data reveal possible positions of the maximal extent of the LIS near the continental shelf edge. The deglaciation on the shelf was rather slow and episodic, as indicated by the presence of grounding-zone wedges, recessional moraines, as well as time-transgressive glacial lineations. Ice retreat in the fjord occurred more rapidly, most likely due to increased water depths. However, the presence of multiple moraine systems reveals periods of ice-margin stabilizations. This study provides additional information to the terrestrial data and, thus, helps improve the models of glacial dynamics in the northeastern sector of the LIS.

POSTER SESSION – IPGS

Geochemical tracers of fluid-rock interactions in exhumed mantle domains: a comprehensive study of serpentinization processes

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In rifted margins, exhumed mantle has extensively interacted with fluids leading to the complete replacement of primary ferromagnesian minerals (mainly olivine, pyroxenes) to secondary hydrous mineral phases (i.e., serpentine minerals) and oxides (e.g., [1]). Such interactions are responsible for important chemical fluxes that are still poorly constrained, as well as the conditions (pH, temperature) in which they occur. Considering that these reactions are involved in major present-day social issues such as natural H2 production, CO2 storage or the formation of seafloor massive sulfide (SMS) deposits [2], we focus our study on material fluxes resulting for fluid-rock interactions and typically observed at rifted margins. We present results of "open-system" hydrothermal experiments where fresh peridotite reacted with seawater at the temperature range of 100-300°C. Secondary mineral phases are identified by XRD, SEM and Raman spectroscopy. The mobility of elements is addressed by systematic measurements of major (μ-XRF and ICP- AES) and trace elements (ICP-MS) in the fluid and solid phases. Experimental results are compared to natural serpentinites from present-day (Iberia-Newfoundland) and Alpine fossil margins. Our experimental results show that, major elements such as Mg, Ca, Na, K and Si are rapidly mobilized in the fluid phase as the reaction proceeds. Among the trace elements, some incompatible elements, including B, Li, and LREE, also concentrate increasingly in the fluid phase. Finally, transition metals such as Cr, Fe and Ni are also significantly mobilized, which may efficiently contribute to the formation of SMS deposits at seafloor.

[1] Marcaillou et al. EPSL, 2011; [2] Marques et al. MG, 2007

Keywords: rifted margins; exhumed mantle; fluid-rock interactions; B-Li-Sr-Nd isotopes;

POSTER SESSION – IPGS

Evolution of hydro-mechanical properties during shearing in an EGS reservoir using a DFN model

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In geothermal systems such as Soultz-sous-Forets, the hydraulic stimulation will ensure the efficient hydraulic exchange between injection and production wells by improving hydraulic conductivity of the fracture network through shear of pre-existing fractures. Shear motion creates permanent changes in hydraulic conductivity because of dilation angle of asperities existed on both sides of fracture planes which in most cases do not match each other after stimulation and create a conduit of open space between. This operation is normally accompanied with microseismicity and is monitored by deploying surface and down-hole seismic receivers.

4-D P-wave tomography derived from seismic monitoring during hydraulic stimulation of well GPK2 of Soultz-sous-Forets, an unexpected occurrence in the P-wave velocity variation. In two steps of stimulation, when the injection flow rate was increased, the P-wave velocity in the stimulated area increased as well (Calo et al., 2011). This is vice versa with what experienced in the laboratory by Lockner et al., (1974) and Rummel (1991), which may be caused by non-linear evolution of hydro-mechanical coupling of discontinuities as explained by Bandis et al, (1983).

Hence, the aim of current project is to numerically model the non-linearity for the elastic response of fractures and to investigate the role of dilatancy associated with shear motions along fractures once they reach instability. 3DEC numerical modeling tools developed by Itasca Consulting Group is used to fulfill the aim of project, considering that dilatancy in 3DEC develops only if shear slip occurs. So far, to pace on abovementioned track, first a numerical model of stochastic discrete fracture network (DFN) based on wellbore scale fracture network description (Massart et al., 2010) is created and after that its effects on mechanical behavior of a 100x100x100 m3 block is investigated.

POSTER SESSION – IPGS

Continuous to intermittent flows in growing granular heaps

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If a granular material is poured from above on a horizontal surface between two parallel, vertical plates, a sand heap grows in time. For small piles, the grains flow smoothly downhill, but after a critical pile size xc, the flow becomes intermittent: sudden avalanches slide downhill from the apex to the base, followed by an “uphill front” that slowly climbs up, until a new downhill avalanche interrupts the process. By means of experiments controlling the distance between the apex of the sandpile and the container feeding it from above, we show that xc grows linearly with the input flux, but scales as the square root of the feeding height. We explain these facts based on a phenomenological model, and demonstrate that our controlled experiments allow to predict the value of xc for the common situation in which the feeding height decreases as the pile increases in size.

POSTER SESSION – IPGS

Surface seaonnal deformations in western Europe computed from a massive GNSS processing of a global network with the GINS/PC software.

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We first process the GNSS solution of a massive europeean network containing almost a thousand stations over twenty years, using a Precise Point Positionning approach with the GINS/PC software developped by the CNES/GRGS. We characterize the spatio-temporal variability of the time series especially the seaonnal variations (which is mostly annual) using a Independant Component Analysis approach. Also, the differences of the spatial variability between each component (East, North, Up) will be determined using the cross-correlated variogramms in order to obtain the optimum smoothing parameters for the inversion of the GNSS displacements. In the other hand, we will focus on the effect of th monumentation of the GNSS stations on the over- or under-determination of the amplitude of the annual signals. Finally, we will take into account the local variations of the crust rheology using the model CRUST 1.0, in the determination of the displacement generated by a surface mass load as part of the Green functions and Love numbers theory. The whole studies conducted should improve the inversion process (find optimum smoothing parameters and use more precise spatial rheological models) of the GNSS displacement to recover the applied surface mass load in order to compare the local hydrology, the GRACE data and several hydrological models.

POSTER SESSION – IPGS

Sensitivity study of Controlled Source Electromagnetic methods to complex conductivity properties of clays

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Contrary to electrical (DC) prospecting methods, Controlled Source Electromagnetic (CSEM) is an imaging technique using a multi-frequency electromagnetic signal [10−2−104 Hz] to obtain the electrical conductivity of the underground, up to 3 km depth. This property is usually considered as a real value and frequency independent. Nevertheless, in some Earth materials, as clayey soils, induced polarization (IP) phenomena are occurring when an electromagnetic perturbation is applied. These mechanisms are described by a frequency dependent complex resistivity. Relaxation model parameters describing these phenomena had shown to be linked to several medium properties, as the type of mineralisation, granulometry, or hydraulic permeability. Obtaining these properties are of great interest in order to characterize clay cap rock, which are a key issue in several contexts (geothermal energy, hydrocarbon, water table contamination,...). Furthermore, if these signals are neglected in CSEM modelling, it can result in an altered image in depth if polarization effect are strong enough. In order to study sensitivity of CSEM method to induced polarization phenomena, complex resistivity was implemented in a 3D Finite-Dierence CSEM modelling code. Sensitivity of electrical and magnetic elds were studied for several acquisition geometry to evaluate the way to maximize polarization responses and parameters controlling the perturbation. It was shown that IP effects can be strong enough to perturb CSEM data, especially on the electrical field at low frequency. The ratio between the imaginary and the real part of conductivity control amplitude of IP effect, whereas imaginary resistivity has negligible effect on the in-phase electrical field. IP effects for frequency higher than 100 Hz will compete induction effect. Conclusions of this study will guide implementation of complex resistivity parameters in the inversion part of the code and help to determine the best inversion strategy.

POSTER SESSION – IPGS

Modeling and Inversion of GPR Signals for Estimating Hydraulic Properties of Unsaturated Sandy Soils

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The evaluation of soil hydraulic properties is important for modeling available water resources and evaluating the dynamics of chemical pollutants in soil. In recent year, geophysical methods have played an important role in hydrology. Our research focuses on using ground-penetrating radar (GPR) for monitoring underground water. First, we changed the depth of the water table and collected data at different times. Then we did processing for data. The third step is to realize the one dimension forward modeling of the data. Finally, we realized the inversion of the water content by comparing the modeling signal with the real signal and backing to modify the water content. Figure 1 shows the part of results of our research. In this experiment, we lowered the water table. In the morning, for each half an hour, we measured one profile by using GPR. In the afternoon, we measured one profile for each hour. Comparing the GPR inversion results of the water content with the water content measured by TDR (Provided by Oliver RAZAKARISOA), it shows that 1) GPR is a good method to realize the inversion of the inversion of the hydraulic parameters. 2) the change of the water content with time from the GPR inversion results at different time. The GPR method is a good method for realizing the inversion of the hydraulic parameters and the water table monitoring. In the future, we will apply the inversion algorithm to realize the inversion automatically.

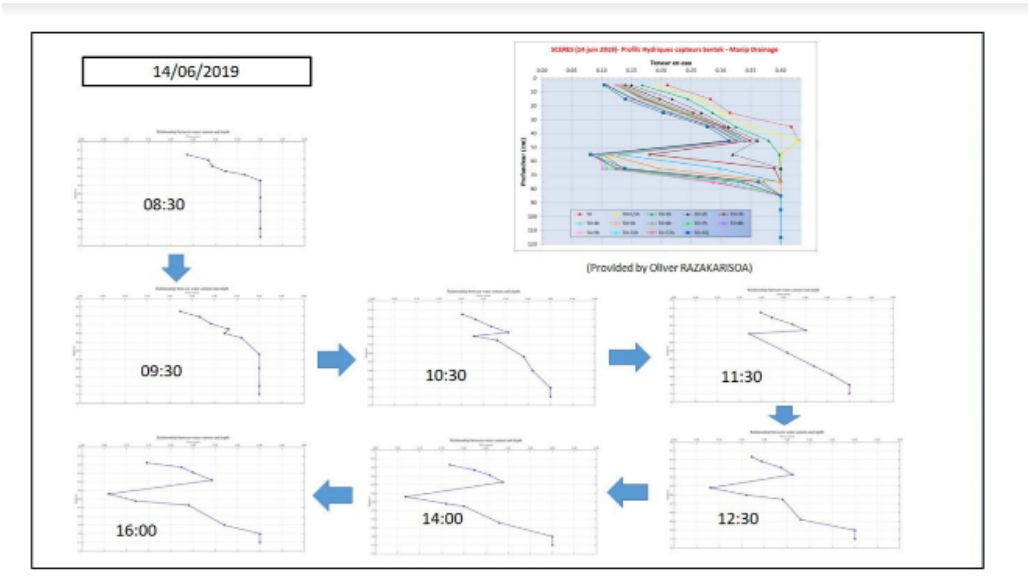

Figure 1: the GPR inversion results of the water content at different times and the water content measured by TDR (Provided by Oliver RAZAKARISOA)

Keywords: Ground penetrating radar; Modeling and inversion; Hydraulic Properties; Unsaturated Sandy Soils

POSTER SESSION - LHyGeS

Conditioning of integrated watershed models by inversion and data assimilation. Needs analysis according to the complexity of the model

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An integrated hydrological model called NIHM (Numerical Integrated Hydrological Model, due to the integration of 3D underground processes into a 2D formalism) was developed at LHyGeS and couples a low-dimensional (2- D) subsurface model to 1-D river flow and 2-D overland flow. The simplification facilitates the calculation but assumes that the heterogeneity of the domain (thus the parametrization of the model) is partly aggregated. It is therefore appropriate to compare the results produced with a more exhaustive approach, in particular the model TRACES (Transport of RadioActive Elements in Subsurface), which handles transient or steady state computation of the flow and transport processes in 2D or 3D heterogeneous domains.

It is, therefore, suited to implement a transport scheme in the simplified model, before adapting the developments already made to the inverse and data assimilation approaches to both models. This exercise will make available two models dealing mainly with flow and time of stay.

The aim of this study is to identify the quantity and type of information that can be used to condition integrated watershed models. First, inverse and data assimilation approaches will be applied to synthetic test cases in order to properly evaluate the impact of different modeling approaches on simulated results. The comparison of the response of different systems will make it possible to determine the optimal parameterization strategies according to the modeling approaches and the available data, and to establish a typology of data and of the optimal technique allowing the best conditioning of a model according to its complexity and its ability to reproduce facts of observation.

Keywords: Low-dimensional model; Integrated hydrological modeling; Adjoint state; Parameter estimation

POSTER SESSION - LHyGeS

Reactive transport of dichloromethane in laboratory aquifers: insights from Compound Specific Isotope Analysis (CSIA) and biomolecular approaches

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Dichloromethane (DCM) is a toxic industrial solvent frequently detected in multi-contaminated aquifers. DCM often co-occurs with chlorinated ethenes resulting in complex mixtures in groundwater that make it difficult to predict its fate. Compound-specific isotope analysis (CSIA) is a useful tool to detect natural degradation of pollutants. Changes in hydrochemistry and redox conditions due to fluctuations in the water table may significantly influence pollutant degradation pathways. In this study, changes in DCM degradation pathways induced by water table fluctuations were examined in laboratory aquifers supplied by polluted groundwater from the industrial site of Thermeroil (France). High resolution vertical sampling and monitoring were performed under steady and transient conditions to examine the aquifers response with respect to hydrochemistry, DCM stable isotope signatures (δ13C, δ37Cl) and microbial composition. Dual C-Cl isotope approach (ΛC/Cl = Δδ13C/Δδ37Cl) was examined to identify DCM degradation pathways. Under the experimental steady conditions, the hydrochemistry showed lower dissolved oxygen (<1.2 mg/L) and increasing Fe2+ concentrations suggesting an iron-reducing prevailing condition. This was further supported by the identification of *Geobacter* sp. In contrast, mass transfer of oxygen increased during the water table fluctuation resulting in more pronounced DCM carbon isotope fractionation (δ13C) indicating a strong enrichment of 13C. Carbon enrichment factors (εC) became larger over time ranging from -20 ± 1‰ to -34 ± 0.3‰. DCM removal (up to 90%) was larger under transient conditions compared to steady conditions (35%). Dual C-Cl isotope plots indicated distinct DCM degradation pathways for steady and transient conditions (ΛC/Cl values of 5.63 ± 0.12 and 11.74 ± 2, respectively). Our results suggest the enhancement of DCM biodegradation under dynamic fluctuations of the water table with a change in DCM degradation pathway. This integrative approach provides insights for potential *in situ* degradation in contaminated aquifers and accounts the effects of dynamic water tables on pollutants degradation.

POSTER SESSION - LHyGeS

Standartox – a tool for assessing the risk of chemicals

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A large number of chemicals such as pharmaceuticals, pesticides and synthetic hormones are in daily use all over the world and enter the environment deliberately or as byproducts of their use. Assessing the risks from chemicals is pivotal to fully capture the pressures on freshwater ecosystems. This is typically done by relating field concentrations to concentrations from standard laboratory tests that cause high mortality or similar effects. However, such data is scattered over multiple databases and requires pre-processing to harmonize units, test results from multiple labs and test conditions. Current (Meta-) Databases such as the Pesticide Property Data Base (PPDB) that standardize toxicity data remain confined to certain classes of chemicals or lack a reproducible process workflow. We developed Standartox – a web application for assessing chemical risks in a standardized way for all chemicals for which results have been published. Standartox works as a Meta-Database that compiles toxicity data from the US EPA ECOTOX data base, physico-chemical and ecological databases, providing standardized toxicity data complemented by physico-chemical characteristics of the chemicals and ecological information of the test species. Hence, Standartox is the first Meta-database that simplifies a reproducible consideration of chemical risks when assessing freshwater ecosystem pressures. We present the application of Standartox for a case study in Romania where derived most-sensitive effect concentrations were used for assessing in-stream chemical risks.

Keywords: ecotoxicology; data analysis; pesticides; statistics

POSTER SESSION - LIVE

Artificial Intelligence to improve Indoor Air Quality?

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We spend about 80-90% of our time in an indoor environment where we breathe between 12 000 L to 15 000 L of air per day. However, indoor air is often more concentrated polluting than outdoor air (WHO, 2014) because of the emissions of materials, furniture, occupants, their activities or air exchange with the outside.
The air quality is monitored mainly by chemical measurements which are usually costly give a very local information. Air quality models emerge to simulate mean pollutant concentrations inside buildings in several rooms. On order to interpret the measurements and to predict the behaviour of pollutants in different scenarios, the INCA-Indoor model was developed (Mendez et al., 2015; Mendez et al., 2016a and 2016b; Rizk et al., 2018; Blocquet et al., 2018). It is a model that simulates into the different physico-chemical processes (chemical and photochemical mechanisms, deposition, sorption, ventilation ...) impacting the concentrations of thousand molecules. It allows today to conduct the analysis of indoor air quality, and supports projects of high environmental performance building designs. But the model cannot represent a varying indoor building occupancy and activities, as well as varying outdoor conditions.
The emergence of reliable sensors with affordable prices allows to acquire in-situ data in the building. The differences observed between the simulations and the measurements offer the opportunity to detect changes in the use of the building and correct some input parameters of the model. Machine learning is tested to proceed to such corrections.

Keywords: Indoor Air Quality (IAQ), Model, Low-cost sensors, Machine Learning

POSTER SESSION - LIVE

Geohistory and geoarchaeology of agrarian landscapes in Grand Est : Shapes, plots and territories

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In this doctoral project in geography, we propose to look at the agrarian shapes of the past and their legacies in the contemporary landscapes of the Grand Est region. In Europe, the vast majority of landscapes are the result of a co-construction between Nature and human. Until the middle of the XXe century, the men who carved the landscape were mainly farmers, organized according to the times collectively and under the aegis of seigniorial or ecclesiastical authorities. In this context, the study of agrarian landscapes makes it possible to better understand human dynamics and their consequences on the temporal trajectories of the Grand Est territory. Indeed, agrarian landscapes are often summarized as openfields and bocage systems. However, many agrarian forms such as lynchets, ridge and furrow, terraces and murgers, attest to a complexity that cannot be satisfied with a two-dimensional reading of the rural landscape. Grand Est bears witness to this diversity of landscapes. The analysis of these shapes at the local level makes it possible to estimate their dynamics. This study is based on several disciplines (pedology, anthracology, geography, history) in order to acquire as much complementary data as possible on agrarian shapes. In the field, we analysed and will analyse lynchets located in Haut Rhin (68) and Moselle (57). A lynchet is a kine of bank that appears on a slope, which results, in most cases, from the erosion of the soil of the plot caused by colluviation or by tillage erosion and sediments accumulation behind a hedge, a pile of stone, a wall... Unlike terraces, lynchets are involuntary forms and not a construction. Indeed, each lynchet corresponds to a plot whose bank represents the limits that allowed the installation of a hedge. The identifications of charcoal and the dates carried out in Obergailbach (57) made it possible to determine the first phases of clearing at the end of the Roman period (321 - 422 cal AD), potentially representing the period of cultivation of these lands, and a second phase located in the Central Middle Ages (1020 - 1155 cal AD), reflecting the complexity of the dynamics of the territory.

Keywords : Agrarian forms, landscape dynamics, lynchets, charcoal, erosion, pedoanthracology.

POSTER SESSION - LIVE

The resilience of the Alsatian aquifer, France to climate and anthropogenic change

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The vulnerability of the Alsatian aquifer to climate change and water abstraction has hardly been investigated whilst climate change impacts such as decreasing snowfall, droughts and heat waves are becoming stronger and water abstraction for irrigation is seasonally intensifying as a result. Despite being influenced by a European temperate climate, seasonal drying of springs and streams have been recently observed in the Middle Alsatian Plain and drought decrees in Alsace have intensified. The Alsatian aquifer, an alluvial aquifer located on the French side of the Upper Rhine, is one of the largest aquifers in Europe. It not only provides drinking water to approximately 1.5 million inhabitants but is also a highly important water supply forindustry and irrigation. This study aims to improve our understanding of the interactions between groundwater levelsof the Alsatian aquiferand river discharge during drought periods. Lying within the Upper Rhine Graben, this complex basin is flanked by the Vosges and Black Forest mountains to the West and East respectively. As such, the aquifer is influenced by both the River Rhine, its main tributaries and the Vosges mountains. At present, it is difficult to differentiate climate and anthropogenic signals in groundwater level lowering. In this study, spatial and temporal correlations of river discharge and groundwater levels are carried out based on meteorological and hydrological data available since 1955 from national and regional agencies, field studies and modelling. A high-resolution analysis at daily time steps is performed at representative sites in Alsace. In a first step, the focus is placed on extreme drought years such as 1976, 2003, 2015 and 2017. Climate change has decreased snow storage and snow water equivalent as well as increasing periods without precipitation and thereby increasing evapotranspiration over the last decades. Even though irrigation represents on average only 26% of groundwater abstraction in the Upper Rhine Department and 11% in the Lower Rhine Department over a territory that is 50% agricultural, water withdrawals are concentrated over a few months and their impacts are visible. First results show a strong link between summer water abstraction for irrigation and drying of streams implying that the impact of water abstraction could outweigh that of climate change during summer droughts. Because they can affect the sustainability of drinking water supply, biodiversity and economic activities, awareness on droughts impacts and water abstraction should be increased.

Keywords: Alsatian alluvial aquifer, climate change, resilience, modelling, groundwater-surface water interactions

POSTER SESSION - LIVE

Industrial releases and its impact on the Upper Rhine river: geo-history and legal approaches

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The Rhine river is used for navigation, irrigation, production of electricity, drinking water and also for the disposal of industrial and urban releases. In the past, these anthropic pressures were not regulated by law, the Rhine river was so polluted that it was once called “the open sewer of Europe”. From the 20th century, important pollution occurred in the Rhine river whether constant or accidental pollution such as the fire in the Sandoz A.G. warehouse in Schweizerhalle, near Basel, Switzerland. The initial factors of industries development on the Rhine were the flourishing of chemical and heavy industries, especially the production of coal in order to supply industry along the Rhine river. Thus, many legal acts such as international agreements, directives of the European Union and intern laws, have been adopted in order to reduce water’s pollution by industries. Indeed, the transboundary water cooperation which is based on shared historical legacy of water governance allowed the improvement of the Rhine river’s water quality over the time. The main goals of this study are to reconstruct the geo-history of industrial pollutions and assess the effectiveness of law with the help of digital tools. Indeed, this research aims to understand better the relation between law and industrial releases by studying the trajectories of the pollutants regulated by European law with the case study of the Upper Rhine.

Keywords: Rhine river; water’s pollution; geo-historical; environmental law

POSTER SESSION - LIVE

Elaborating, deploying and adapting the management on the Rhine fluvial hydrosystem: construction of a methodology for participatory and adaptive management

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The need to manage aquatic and riparian habitats in an integrated and participatory manner is increasingly seen as crucial regarding the implementation of environmental policies, particularly in a context of global change. This thesis focuses on protected natural areas in the Upper Rhine fluvial hydrosystem, including the main channel, the floodplain and side channels. The protection and restoration of these wetlands and riparian habitats is a major issue on both national and European scales, because of the importance of the ecosystem services they provide, (e.g. food mitigation, groundwater resource renewal, biodiversity and adaptation to climate change). The objective of this thesis is to diagnose the current management of natural areas and to develop a participatory and adaptive management approach. To achieve this objective, we are working on 3 research axes which are: I) Understand management approaches, II) Evaluate management approaches and methodologies and III) Build a participatory and adaptive methodology. The present work is based on decision sciences and participatory sciences and involves the method of reconstructing decision-making processes. Our results highlight important methodological weaknesses which may significantly impair the manager’s actions. Our results also show that current management practices do not fully incorporate the concepts of " integration of different stakeholders " and "adaptation", which may weaken the effectiveness and sustainability of management actions. The ambition is to propose a set of conceptual and methodological recommendations aimed at clarifying the procedures for an integrated management of natural areas. These recommendations will focus on the main stages of management and involves a procedure for carrying out the diagnosis and evaluation phases through a participatory approach, as well as the proposal of a control and surveillance system that allows the adaptability of actions throughout the execution of the management plan. We conclude by arguing that these recommendations can be reproduced and transposed to other natural aquatic and riparian areas, in France and elsewhere.