Abstract Book

13th Annual PhD Day

March 13, 2018

PhD Day 2017 at the GFZ
Programme

08:00–08:45  Registration
09:00–10:30  Introduction/Information talks (Geodocs, Mr. Hüttl, Ms. Hüttges, Personalrat, HelmholtzJuniors), Election of new GeoDocs and HelmholtzJuniors
  Coffee
10:45–11:15  Invited Talk by Prof. Dr. Niels Hovius
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12:15–12:25  Group photo with Ms. Gantz
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  Coffee
13:45–14:45  Postersession II (even Poster No.) and PICO Presentations
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PICO talks: 13:15 – 13:45

PICO Presentations: 13:45 – 14:45
Transient Effects of Groundwater Pumping on the 3D hydrothermal configuration of Berlin

Maximilian Frick
mfrick@gfz-postdam.de

Maximilian Frick, Mauro Cacace, Magdalena Scheck-Wenderoth, Michael Schneider, Nasrin Haacke
GFZ Potsdam, GFZ Potsdam, GFZ Potsdam, FU Berlin, TU Berlin

The major objective of this study is to understand the hydraulic and thermal state of the subsurface beneath the major urban center of Berlin, capital city of Germany. To achieve this goal, we implemented newly available hydrogeological data, which have been used to parametrize the 3D models of this study in space and time regarding hydraulic connectivity of surface water resources to the subsurface as well as groundwater extraction for supply purposes. The model area is located in the Northeast German Basin and consists of a sequence of sedimentary deposits of several kilometres thickness. The sedimentary succession consists of alternating aquifers and aquitards deposited during Cenozoic times. This succession contains the freshwater aquifers that are used for municipal water supply. These are separated from the deeper saline aquifers by the local Oligocene Rupelian aquitard, which displays a heterogeneous thickness distribution due to glacial erosion, being discontinuous in some places. Based on newly available data and aided by previous modelling studies, we found that leakage of deeper saline water through the main target aquifer is more widespread and not limited to places where the main aquitard sequence has been eroded. Pervasive leakage in and from the Rupelian aquitard (possibly leaching into the fresh water aquifer) is observed to occur also in areas where the clay layer is present in correlation with a relative strong component of hydraulic forcing from the surface. We present results of both, the qualitative and quantitative effects of the modified hydrothermal setting of the different model scenarios, focussing on the effects of large-scale groundwater pumping.
Methane producing archaea in Siberian permafrost in their response to thaw

Stine Holm
5.3 - Geomicrobiology

Stine Holm , Fabian Horn, Christian Knoblauch, Josefine Walz, Dirk Wagner, Susanne Liebner
Helmholtz Centre Potsdam - GFZ German Research Centre for Geosciences, Section 5.3. Geomicrobiology, Potsdam, Germany, Department of Earth Sciences, Hamburg, Germany

Methane production in thawing permafrost can be substantial but often evolves after long lag phases or is lacking, potentially a result of low or absent methanogenic community or limited substrate. We investigated samples of a permafrost core of Kurungnakh Island, Siberia, seeking an explanation on the contrasting evolution of methane production after permafrost thaw. Subsamples were incubated anaerobically at 4°C for 7 years. The enumeration of methanogenic mcrA gene copies was performed by quantitative PCR (qPCR) and the community composition was determined by amplicon based sequencing. The initial community of the upper layer of the core, formed during cold and dry conditions was dominated by Thaumarchaeota. These samples did not show methane production by the end of the incubation experiment. In contrast, the layers below 9m deposited under warm and wet conditions established methane production and were dominated by Euryarchaeota, with a high abundance of methanogens (47-78%). During the incubation the diversity of these samples decreased to a dominance of Methanomicrobiales. Based on methane production, community analysis and qPCR results, we conclude that thaw stimulated methanogenesis in permafrost environments where an initial active methanogenic community was present. The response of the methanogenic community appears to depend on the conditions, under which the soil was formed, with warmer and wetter conditions enhancing the activity of methanogens after thaw.
Ni and Pt in high-temperature H2O+HCl fluids

Lea Scholten

4.3 - Chemistry and Physics of Earth Materials

Lea Scholten, Christian Schmidt, Oliver Beermann, Anke Watenphul, Doreen Ames, Denis Testemale
GFZ Potsdam/Christian-Albrechts-Universität zu Kiel

In hydrothermal environments, Ni and Pt occur mainly in divalent oxidation state as arsenide and sulfide minerals. The solubility of Pt in hydrothermal, generally Cl-bearing, fluids appears to be much lower than that of Ni. A few occurrences of PtAs2 (sperrylite) are suggested to be related to hydrothermal fluids [1] as well as an overall enrichment of Pt relative to Ni, e.g. in the footwall-type deposits of the Sudbury District [2]. This suggests that As may foster precipitation of Pt ore minerals. The role of S and As ligands on the solubility and complexation of Ni and Pt in hydrothermal fluids is addressed in this study by in-situ synchrotron XRF- and XAS- and Raman spectroscopy on solubility experiments. The solubility experiments were carried out with NiS and NiAs (nickeline) at 80 MPa in 0.1 and 1 molal HCl at 400 °C and with PtAs2 and Pt metal in 1 and 6.86 molal HCl at 500 °C. The amount of Pt in the fluid was very low, max. 8·10⁻⁵ molal by dissolution of Pt metal in 6.86 molal HCl. NiS dissolved congruently from 7.2·10⁻³ to 8.72·10⁻² molal Ni with increases in HCl from 0.1 to 1 molal. NiAs dissolved incongruently with slightly more As dissolved than Ni. Even after >16 h Ni and As contents were still rising to max. 3.6·10⁻³ and 2.7·10⁻² molal Ni and 2.5·10⁻³ molal and 2.0·10⁻² molal As in 0.1 and 1 molal HCl, respectively. XANES spectra indicate the presence of As as oxidized As(V) and of Ni as Ni(II) and, supported by literature data [3, 4], no complexation of Ni with As or S. Raman spectra of HCl solutions reacted with NiS up to 600 °C and 1.15 GPa showed Ni-Cl complexation with contact ion pairing at ≥300 °C and below 600 MPa. No complexation of Ni with S was detected. These results show that Ni is readily mobilized from NiS and NiAs by acidic chloridic hydrothermal fluids and that Cl is the dominating complexing anion. That Pt remains nearly immobile suggests that the Pt enrichment relative to Ni and the occurrence of sperrylite in the Sudbury deposits are rather related to magmatic than to hydrothermal processes. The results indicate that arsenate species are more stable in hydrothermal fluids than previously thought and that the redox reactions involving As may be crucial for the mobilization and precipitation of arsenide ore minerals.

1 Pénalez, A. et al., 2008. Econ. Geol. 103, 1005-1028.
A0 posters

Poster Session 1: 11:15 – 12:15
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Poster Session 2: 13:45 – 14:45
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Poster No. is NOT the page Number!
Impact of Geogenic CO2 on deep microbial ecosystems in the Hartoušov mofette system, NW Bohemia

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A mofette is a natural cold either dry or wet gas vent releasing CO2-rich gases into the atmosphere. The Hartoušov mofette system is located in the northern Cheb Basin (NW Bohemia, Eger Rift). The area is characterized by lithospheric mantle-derived gas emanations (>99 % CO2). The exhaling free gas phase of the Bublak mofette, near the Hartoušov mofette system, is characterized by a subcontinental mantle helium isotope signature of 5.9 Ra and a d13C signal of ca. 2 % (Bräuer et al., 2011). The relatively high d13C signal bears the opportunity to trace the incorporation of geogenic CO2 into microbial biomass. The objective of this study is the investigation of the impact of geogenic CO2 on deep microbial communities and their surrounding sedimentary life habitat. In early 2016 a 108.5 m deep borehole was drilled by GFZ as a preliminary study for the PIER-ICDP study - drilling the Eger Rift (DFG Alawi, AL 1898/1). The drilling was performed in a mofette system near the village of Hartoušov. During drilling CO2-rich sediments were recovered between 71 m and 81 m depth and at 78.5 m depth a CO2 blow out occurred suggesting a CO2 reservoir in this core interval related to an aquifer between 79 m – 85 m. In consequence the core interval between 65 m and 95 m was selected for further investigations. Lithologically, this core section is composed of three different units that are (from the bottom to the top): a weathered Palaeozoic mica schist (95 m – 91.5 m depth), a compact, sandy Miocene claystone with lignite fragments and root structures suggesting soil horizons and deposition in a swamp environment (91.5 m – 78.5 m) as well as a laminated to bedded, calcareous, sandy or peaty Miocene mudstone interbedded with bioclastic carbonates, dolomite beds and gypsum layers of lacustrine origin (78.5 m – 65 m). The sediments exhibit natural deformation structures in form of small faults, dykes and sills all indicating hydrofracturing and sediment fluidization resulting from high pore fluid pressures. The sediments in the vicinity of these deformation structures are infrequently cemented by carbonate or gypsum and can exhibit changes in color (Bussert et al., 2017). TOC is absent in the Palaeozoic basement, increases towards the top of the swamp sediments, and is high but variable in the lacustrine sediments. A TOC/TN ratio higher than 20 for all sediments indicates higher plants as main source for organic matter. First results from past microbial biomarker analysis show the presence of branched and isoprenoid GDGTs with highest contents in the lacustrine sediments. However, TOC-normalized highest GDGT contents can be observed in the CO2 reservoir interval. Compound specific carbon isotope analysis will be conducted to examine whether there is a link between GDGT abundance and CO2 availability. A relative high abundance of branched GDGTs in swamp and lacustrine sediments points to a dominance of soil-derived material. The hopanoid biomarkers also confirm swampy environmental conditions at the beginning of the Miocene sedimentation and suggest a transition to lacustrine conditions. Bulk d13Corg data reveal a C3-plant signal which changes in relation to the lithological units. Interestingly, the bulk d13Corg of the swamp sediments plot at higher values than those from the lacustrine sediments. Similar values were determined by Wohlfart (2008) for CO2 influenced surface soils directly from the Hartoušov mofette area. Compound specific d13C values of bacterial hopanoids show a similar trend across the transition from the swamp to the lacustrine deposits. Unravelling changes of the isotope data as result of different paleofacies or of different impact of exhaling CO2 on the biomass during the past will be in the focus of the ongoing studies in the project. In addition to past microbial and vegetational biomarkers also markers for living microorganisms (intact phospholipids and PLFAs) and their carbon isotope signature will be investigated.
Combined convective and diffusive modeling of the ring current and radiation belt electron dynamics using the VERB-4D code

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2.8 - Magnetospheric Physics

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Ring current and radiation belts are key elements in the global dynamics of the Earth’s magnetosphere. Comprehensive mathematical models are useful tools that allow us to understand the multiscale dynamics of these charged particle populations. In this work, we present results of simulations of combined ring current - radiation belt electron dynamics using the four-dimensional Versatile Electron Radiation Belt (VERB-4D) code. The VERB-4D code solves the modified Fokker-Planck equation including convective terms and models simultaneously ring current (1 – 100 keV) and radiation belt (100 keV – several MeV) electron dynamics. We apply the code to the number of geomagnetic storms that occurred in the past, compare the results with different satellite observations, and show how low-energy particles can affect the high-energy populations. Particularly, we use data from Polar Operational Environmental Satellite (POES) mission that provides a very good MLT coverage with ~1.5-hour time resolution. The POES data allow us to validate the approach of the VERB-4D code for modeling MLT-dependent processes such as electron drift, wave-particle interactions, and magnetopause shadowing. We also show how different simulation parameters and empirical models can affect the results, making a particular emphasis on the electric and magnetic field models. This work will help us reveal advantages and disadvantages of the approach behind the code and determine its prediction efficiency.
Wood anatomical parameters from European oak and Scots pine for reconstructing climate in temperate lowlands

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5.2 - Climate Dynamics and Landscape Evolution

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Tree-ring based climate reconstructions from temperate lowland environments are largely missing due to diffuse climate signals when using traditional dendrochronological methods. Developments in quantitative wood anatomy indicate that cell anatomical features may carry additional environmental information that could assist climate reconstruction. These recent advancements motivated us to analyse cell structures in two tree species, the European oak (Quercus robur L.) and Scots pine (Pinus silvestris L.), as they are widely distributed across European temperate lowlands, and their common use in building materials over past centuries could possibly assist in the development of centuries-long chronologies. We combined material from living trees with historical building timber from temperate lowland forests in northern Germany and Poland covering the period AD 1300 to 2016. In two separate studies approximately 46,000 earlywood oak vessels from 96 trees, and 1.2 million tracheid cells from 41 pine trees, were measured using flatbed scanner (oak vessels), confocal laser scanning microscope (pine tracheids), and image analysis tools (ROXAS). Our analysis confirms that chronologies of both oak earlywood vessel and pine tracheids contain climate signals that are different and stronger than those of corresponding tree ring-width chronologies. Additionally, by applying very little detrending to the chronologies, it may be possible to preserve low-frequency climate signals. Our analysis confirms that anatomical parameters and their relation to climate provide additional climate proxy information within wood structure, however, these are yet to be fully explored. This information will be crucial in extending climate reconstruction records into largely unexplored geographic regions.
Estimating integrated water vapour trends from VLBI, GNSS and numerical weather models: sensitivity to tropospheric parameterization

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In this study, we estimate integrated water vapour (IWV) trends from very long baseline interferometry (VLBI) and global navigation satellite systems (GNSS) data analysis, as well as from numerical weather models (NWMs). We study the impact of the modelling and parametrization of the VLBI tropospheric delay on IWV trends. We address the impact of the meteorological data source utilized to model the hydrostatic delay and the thermal deformation of antennae, as well as the mapping functions employed to project zenith delays to arbitrary directions. To do so we derive new mapping functions, called Potsdam mapping functions (PMF) based on NWM data and a new empirical model, GFZ-PT. GFZ-PT differs from previous realizations as it describes diurnal and sub-diurnal in addition to long-wavelength variations, it provides harmonic functions of ray-tracing-derived gradients, and it features robustly estimated rates. We find that alternating the mapping functions in VLBI data analysis yields no statistically significant differences in the IWV rates, whereas alternating the meteorological data distorts the trends significantly. Moreover, we explore methods to extract IWV given a NWM. The rigorously estimated IWV rates from the different VLBI setups, GNSS, and ERA Interim are intercompared, and a good agreement is found. We find a quite good agreement comparing ERA Interim to VLBI and GNSS, separately, at the level of 75%.
Characterizing subsurface hillslope-stream connectivity at multiple sites with salt water injection and time-lapse ERT

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5.5 - Earth Surface Process Modelling

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Lateral subsurface hillslope-stream connectivity and its dynamics and spatial variability are an important factor to better understand and simulate runoff generation. In this investigation infiltration experiments from a trench with salt water were conducted and changes in electric conductivity (EC) were visualized via three continuous ERT transect measurements – two across and one along the hillslope – and EC measurements in piezometers and in the stream. In total six experiments were conducted at the hillslope-stream interface in the Attert Catchment, Luxembourg – two in each of the three main geologies: marls, schist/slate and sandstone. Hand-dug trenches (7 m long and 40 cm deep) were used for infiltrating salt water for several hours into the subsurface, which allowed to focus on subsurface flow processes. The spatio-temporal changes in EC in the soil were monitored by time-lapse ERT to identify the establishment of flow paths or flow regions. For one of the experiments additional time-lapse GPR measurements were used to obtain complementary information. In addition, EC in the streamwater above and below the tested hillslope was measured, as well as the shallow ground water level at seven piezometers deployed on a regular grid between the infiltration trench and the stream. The former allowed us to observe the establishment of connectivity between hillslope and stream whereas the latter detected state changes and possible steady state conditions. The combined information of the various data sources provides a comprehensive image of how hillslopes and streams connect in three different geologies. For marls, fast EC responses in several piezometers were detected, despite the low hydraulic conductivity, implying lateral preferential flow. Schist/slate shows fast and deep vertical infiltration patterns and water level responses only at the piezometers closest to the stream, indicating subsurface connectivity at the weathered soil-bedrock interface. Sandstone developed surface puddles close to the infiltration trench suggesting reduced lateral flow towards the stream.
Discovering events beyond the catalog: Matched filter application to the Eastern Sea of Marmara

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Over the last decade earthquake research has experienced a significant surge in available ground-motion recordings and associated data quality, leading to a point where the amount of continuous datasets has surpassed our previous processing capabilities. Large parts of the occurring micro-seismicity goes unnoticed when using traditional energy-based earthquake processing techniques, such as STA/LTA detectors. However, recovering these missing events and obtaining a more complete catalog down to small magnitudes is not only important for understanding physical mechanisms of earthquake nucleation and interaction, but also useful for seismic hazard forecasting and mitigation. Here, we adapt for the first time state of the art waveform based earthquake detectors to continuous data recorded by the GFZ plate boundary observatory (GONAF) in the Eastern Sea of Marmara, Turkey. Combining these newly detected earthquakes into dense catalogs should illuminate active fault structures and track the evolution of fault slip. This will help to better understand and assess the seismic hazard for the region, where a magnitude up to 7.4 earthquake is expected in the near future just offshore the Istanbul metropolitan region and its 15 million inhabitants.
Spatio-temporal changes of coda quality factor in The Geysers geothermal field

Aglaja Blanke
4.2 - Geomechanics and Rheology

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In this study we use 725 seismic events, recorded at The Geysers geothermal field, California, to estimate the coda quality factor, Qc. The induced earthquakes with duration magnitudes from Md 1 to Md 4 have been recorded using the Berkeley-Geysers seismic network, consisting of 31 short-period surface instruments. The analyzed events located at depths of ∼3 km form a tight cluster related to the water injections into the wells Prati-9 and Prati-29. The epicentral distances between cluster and stations range from 0.69 to 15.31 km. To calculate the coda quality factor (Qc) we use the single scattering model extended by Phillips and Aki (1986), where the recorded S-wave coda results from scattering of the direct S-wave on numerous randomly distributed heterogeneities in the earth’s crust. Later parts of the S-wave coda (different lapse times) are separated into a sequence of overlapping time windows. For each window, the average Power Spectral Density is calculated and the coda amplitude is extracted at fixed center-frequencies ranging from 1 to 69 Hz. In the following, the decay of the coda wave with time around a set of frequency bands is analyzed by using the regression analysis, leading to Qc estimates and their associated uncertainties for particular frequencies. Simultaneously, we investigate the sensitivity of Qc estimation to different input parameters including lapse time, magnitude, window width of moving windows, taper and seismic sensor components. We confirm that on average our estimates are insensitive to the magnitude, sensor component and taper. Small variations in Qc estimates are observed testing different window widths and lapse times. We identify major variations in our Qc estimates while testing different levels of signal-to-noise ratios and slope errors of the regression analysis. The resulting high-quality Qc estimates were further tested in the context of their spatio-temporal behavior in the reservoir. Therefore, we investigate the distance and azimuthal dependence of Qc, and relate it to the observed induced reservoir anisotropy and local geothermal features. In addition, we analyze the influence of seasonal changes in the injection rates on our Qc estimates. Finally, we compare the stability of our coda-Q results with estimated S-wave quality factors from the spectral analysis and discuss them in the context of source parameters uncertainties and the potential bias of their estimation.
Detection of Methane Emission Point Sources using high-resolution hyperspectral Satellite Data based on Radiative Transfer Simulations

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1.4 - Remote Sensing

The detection of methane emission point sources from space becomes more and more important since methane is one of the mean drivers of climate change. It is emitted by both anthropogenic sources like livestock, oil-gas systems, landfills, coal mines, wastewater management or rice cultivation, as well as by natural sources like wetlands, inland waters or termites. An accurate monitoring of methane from space is challenging because of its relatively small signal in comparison to other atmospheric constituents, but advances in both sensor technology and retrieval models are leading to an increasingly accurate detection. This is opening the door to high-resolution spaceborne measurements, which would be the key to quantify emissions from point sources like coal mines, ventilation shafts or landfills. The hyperspectral Environmental Mapping and Analysis Program (EnMAP), scheduled for launch in 2020, offers the potential to detect methane emission point sources with its spatial resolution of 30 m. In this work, atmospheric methane concentrations will be inferred from simulated EnMAP spectra by applying a forward operator based on radiative transfer simulations from the matrix-operator model MOMO. The Next Generation Airborne Visible/Infrared Imaging Spectrometer (AVIRIS-NG) has proven to be a realistic proxy for future EnMAP based retrievals, however, spatial resampling from 4 to 30 m as well as spectral conversion from 5 to 10 nm resolution can lead to accuracy loss. Furthermore, the simulation of EnMAP radiometric characteristics is not straightforward. Therefore, the sensitivity of the retrieval regarding radiometric, spectral and spatial characteristics including the influence of different surface types will be investigated, first using AVIRIS-NG data and afterwards applying the algorithm on simulated EnMAP products. Finally, alternative retrieval techniques like machine learning models using neural networks will be evaluated regarding processing speed and accuracy.
Flood loss and multi-risk exposure model in the context of the RIESGOS project

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In early 2017, the coast of Peru has been hit by an El Nino-induced flood of historical scale, resulting in 1.7 million affected people, among them at least 158 dead, over 31 000 entirely collapsed houses, and severe damage to infrastructure and economy (reported as of June 2017). This event once more demonstrated the vulnerability of the region to geohazards, despite broad awareness of the issue. The RIESGOS project – a cooperation with the German Aerospace Center (DLR) and several business partners – aims at developing modern multi-risk analysis and information system components for the Andes region. This interdisciplinary approach will comprise information on floods, earthquakes, tsunamis, landslides, and volcanic hazards. Especially the common exposure and vulnerability to floods and earthquakes will be investigated by the GFZ in close cooperation between the sections 5.4 (Hydrology) and 2.6 (Seismic Hazards and Risk Dynamics). For the presented PhD topic, the two main objectives are: (1) modelling flood risk (loss) based on provided hydraulic scenarios and satellite imagery, using cutting-edge methods like Bayesian networks and ensemble simulations. (2) Researching a novel taxonomy and parameters for multi-risk exposure. During the first phase, empirical data will be collected together with South American partners via direct interviews and on-site inspection of flood damage. Parameters for the models – e.g. water depth, flow velocity, duration of flooding, but also building characteristics like footprint or material – will then be derived from this survey. In addition, it is proposed to integrate modern data sources, such as OpenStreetMap or 3D city models, and to make use of the DLR’s latest satellite platforms to gather up-to-date information on areas, which are yet sparsely covered. The final result is expected to be a set of flood risk maps for case study areas, including a measure of uncertainty, which will further be used as components for the RIESGOS information system.
A0 posters: Poster Session 2: 13:45 – 14:45

Effects of temperature and fluid chemistry on permeability variations in illitic sandstone

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6.2 - Geothermal Energy Systems

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The circulation of permeating fluids within a geothermal reservoir will change the temperature distribution and the equilibrium between minerals and the pore fluid, both which affect the permeability of the reservoir formation. In our laboratory study, X-ray diffraction showed that Flechtinger sandstone cores contain mainly illite as the clay phase. Flow-through experiments revealed large range variations of up to three orders of magnitude in permeability due to temperature increases and changes in the concentration and composition of the permeating fluids. Mercury injection porosimetry and scanning electron microscopy measurements of the same starting material and the treated samples indicated changes in pore distribution and microstructure prior to and after the experiments. A temperature increase resulted in an irreversible damage of permeability in both distilled water-saturated and NaCl solution-saturated samples. Exchanging the preexisting high salinity NaCl solution by distilled water caused a further drastic permeability decrease at both 28 °C and 144 °C, while the permeability was progressively restored to 40% of the starting value by reintroducing the 2.0 mol/L NaCl solution. Furthermore, a subsequent fluid exchange by a 2.0 mol/L KCl solution fully restored permeability to its initial value. Subsequent replicative steps showed a similar behavior but with smaller variations in permeability. The study indicates two processes of permeability damage. Residual thermal strain compresses the illite lined on the walls of the pore surface causing the closure of pore throats. The so compressed fibrous illite then is hard to be redistributed and thus permeability is less sensitive to temperature changes afterwards. Na+ and K+ ions will change the ionic content of illite by replacing exchangeable cations. The weak swelling of edge illite platelets and the repulsion of illite booklets can further block pore throats causing permeability damage. This behavior is controlled by cation varieties and concentrations which determine the structure of illite.
A magnetotelluric profile across the Mérida Andes (Venezuela)

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The Mérida Andes are a major mountain chain and dominate the geographic appearance of western Venezuela. The northeast-trending intracontinental orogen emerged in the middle Miocene due to the lateral strike-slip convergence between the Caribbean and South American Plates. We report on a magnetotelluric (MT) study which was conducted in 2015, as a part of the GIAME (Spanish acronym stands for Integrated Geoscience of the Mérida Andes) project, a multidisciplinary project aiming to determine the internal structure and the deep roots of the orogen. The main profile extends for 240 km across the central part of the MA. Overall we recorded 5-component MT broadband data at 70 sites in the frequency range from 10 kHz to 1 mHz. Phase tensor (Caldwell et al, 2006) and strike analysis based on data ellipticity (Becken and Burkhardt, 2004) indicate a complex subsurface with strong 3D features off-profile. To examine the resolution potential of 3D inversion with data collected along a profile, we created a synthetic 3D MT dataset mimicking the main geological features and topography. We also used this model to optimize grid dimensions and mesh design. Inversion of the synthetic dataset was started with 100 Ωm half-space model representing an average for crustal resistivities and including topography. After 28 iterations a RMS of 1.04 was reached, suggesting an excellent data fit. 3D inversion successfully recovered major features of the resistivity structure. In particular, sedimentary basins such as Barinas – Apure and Maracaibo basins were well recovered in both depth and resistivity values, 5 km – 5 Ωm and 10 km -15 Ωm respectively. The high resistivities of the MA and background (300 Ωm ) were recovered beneath the stations up to 80 km depth. Yet, at depths >80 km and distances >20 km the initial model remains practically unchanged and outlines the limits of resolution capabilities of the synthetic profile dataset. Generating a geoelectrical model up to 60 km depth is one of the main objectives of this project, which is proved then achievable.
Surface load controls on shape of shallow magma storage zone

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2.1 - Physics of Earthquakes and Volcanoes

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Volcanic edifice generates stresses in the crust comparable to the order of magnitude of tectonic stresses. We investigate how the geometry of the load provided by a growing volcanic edifice sets a top-down control on the shape of the magma reservoir. 2D mechanical simulations of ascent pathways of magma in the crust are carried out for different shapes of surface edifice. We compiled data on the shape and depth of magma storage of deforming volcanoes from available databases (COMET, Smithsonian). Based on the selected cases, numerical simulations and crustal deformation studies reveal broad patterns that fit well with the idea that surface load plays a strong control on the shape and depth of the magma storage system. Calderas are associated to sills or top-flatted reservoirs, while stratovolcanoes are related to vertically developed reservoirs such as ellipsoids. The results on the relationship between the shape of edifice and magma reservoir opens a new perspective on magma reservoir research.
Slip on wavy frictional fault surfaces: is the 3rd dimension a sticking point?

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Using the 3D triangular displacement discontinuity boundary element method with frictional constraints we simulate slip on fault surfaces. The method's accuracy in comparison to analytical solutions is quantified. We show how this can be used to approximate stress intensity factors at the crack tips. Using this method, we go on to quantify how slip is reduced on fault surfaces under boundary conditions such that they are optimally orientated for shearing in 3D. Fault surface topography is approximated as a sinusoidal waveform, i.e. corrugations. We show that slip reductions relative to planar faults for 2D line and 3D penny-shaped crack models are comparable within 10% when slip is perpendicular to the corrugations. Using the 3D model, we then show how slip is reduced more when corrugation wavelengths are doubled compared to the reduction due to corrugation alignment with the slip direction. When slip is parallel with the corrugation alignment we show that reducing the out-of-plane stress, from the normal traction acting on the fault when planar to that resolved on a perpendicular plane, has the same effect as halving the length of the corrugation waveform in terms of slip reduction for a given amplitude.
The source of ore fluids in the epithermal Sn-Ag-(Zn) Pirquitas deposit, NW Argentina: fluid inclusion and isotopic constraints

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3.1 - Inorganic and Isotope Geochemistry

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The Pirquitas Sn-Ag-(Zn) deposit in northwestern Argentina is a vein-type epithermal deposit thought to be the southernmost analogue to the Sn-Ag deposits of the southern Bolivian Tin Belt (BTB). Those deposits formed from magmatic-hydrothermal fluids related to the Miocene volcanic arc, but little is known in detail about the origin and evolution of ore-forming fluids at Pirquitas. That is the aim of this study, which combines analyses of fluid inclusions in quartz, sphalerite, Ag-Sn sulfides, and Ag-rich sulfosalts with noble gas isotope data from fluids released by crushing bulk samples, and with lead and sulfur isotope ratios determined in ore minerals. Mineralization occurred during two events (event I and event II). The first one records the highest homogenization temperatures, up to 375°C, in early pyrrhotite-pyrite-quartz-cassiterite assemblages. Salinity of fluid inclusions in the early quartz ranges between 0 and 7.5 wt.% NaCl. Later assemblages of Sn-Ag-Pb-Zn-sulfides and Ag-rich sulfosalts yield higher salinities, up to 10.6 wt.% NaCl, and homogenization temperatures between 213 and 274°C. This evolution within event I is attributed to a new pulse of saline magmatic fluids to the hydrothermal system. Event II formed the most economic Ag mineralization and is characterized by early colloform cassiterite and sphalerite as well as various Ag-Sn-Bi-Pb-Cu-Sb sulfosalts. Homogenization temperatures were between 190 and 252°C and salinities between 0.9 and 4.3 wt. % NaCl. The noble gas isotopic analyses of ore-hosted fluid inclusions from all samples but one show 3He/4He ratios between 1.9 and 4.1 Ra. Those ratios plot in the range of published data from the nearby volcanic arc and were somewhat higher than typical values of meteoric water-derived hotsprings in the region. This suggests a significant contribution of magmatic fluids to the Pirquitas mineralization although no intrusive rocks are exposed in the mine region. A magmatic origin is supported by the ore δ34S values between -3.3 and 2.0 ‰. The Pb isotopes ratios from Pirquitas ores compared with other data from polymetallic deposits from the BTB designate the Ordovician metasediments as the main source of the lead. The lead was brought in the hydrothermal system by igneous activity as it can be observed in a deposit like Cerro Rico de Potosí.
Strain Localization and Weakening Processes in Viscously Deforming Rocks: Numerical Modeling Based on Laboratory Torsion Experiments

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2.5 - Geodynamical Modelling

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Deformation localization is ubiquitous in earth materials and observed over a broad range of scales in space and time. Localization processes in the viscous crust lead to the formation of deformation zones that can induce brittle responses in the upper crust and govern plate tectonics. To get detailed insight into the evolution of strain localization and weakening processes in viscously deforming rocks we closely link our numerical models to rheological experiments. Furthermore, we test if simple piece-wise linear functions for the parametrization of weakening should be based on finite viscous strain or deformation work. Our 2D Cartesian models are benchmarked to single inclusion torsion experiments performed at elevated temperatures of 900 °C and pressures of up to 400 MPa (Rybacki et al., 2014). The experiments were performed on Carrara marble samples containing a weak Solnhofen limestone inclusion at a maximum strain rate of 2.0*10^{-4} s^{-1}. Our models are designed to reproduce shear deformation of a hollow cylinder equivalent to the laboratory setup, such that material leaving one side of the model in shear direction enters again on the opposite side using periodic boundary conditions. Similar to the laboratory tests, we applied constant strain rate and constant stress boundary conditions. We establish a virtual way of getting insights into process zone evolution with the aid of a simple weakening law that can mimic rheological weakening. Constant strain rate and constant stress experimental results are successfully reproduced using either finite viscous strain or deformation work based weakening laws. Both yield the same result for this setup. We find that local stress concentrations at the inclusion tips initiate strain localization inside the matrix and that rheological weakening is responsible and required to establish a shear zone in the matrix. This area of ongoing weakening – the process zone – expands with time from the inclusion tips into the matrix In nature the magnitude of weakening can be bigger than what we get due to larger scale effects like shear heating. So in this aspect we establish a minimum constraint on viscous strain softening.

Light dependent photosynthetic performance of key Mediterranean rocky shore algal reef builder

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Vermetid-reefs in the Mediterranean Sea and rocky shores are hot-spots of biodiversity, often considered as the subtropical equivalent of coral reefs, with economic and cultural importance. The development of the reefs depend on the actively of several reef builders including the red Crustose Coralline Alga (CCA), Neogoniolithon brassica-florida (hereafter Neogoniolithon). Despite its importance, little is known about the short term acclimation to fast changes in the light intensity and the corresponding photosynthetic activity. To overcome the large spatial variability in the light field (due to location and the rugosity of the rocks) we grew Neogoniolithon on glass slides and characterized its photosynthetic performance in response to various illuminations by following the O2 exchange and fluorescence parameters. Generally, when grown under low illumination such as in protected niches were the light intensity is about 1% of surface illumination Neogoniolithon exhibits the fastest photosynthetic rate. When exposed to light intensities higher than experienced during growth Neogoniolithon activate adaptive/protective mechanisms such as state transition and non-photochemical fluorescence quenching (NPQ). We find that the variable fluorescence parameter, Fv/Fm, is not suitable to assess photosynthetic performance in Neogoniolithon and proposed an alternative recently developed. Our findings help to clarify why Neogoniolithon is usually observed in shaded niches and as a cryptic flora along the reef surfaces.
Analysis of NSO compounds in oil-bearing fluid inclusions

Yufu Han

3.2 - Organic Geochemistry

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Oil-bearing fluid inclusions (FIs) in minerals such as quartz, carbonates etc. contain aliquots of fluids trapped within cavities during crystallization or re-crystallization of secondary cracks in the presence of a fluid phase. Geochemical information from these oil inclusions can be used to compare present and palaeo-oils and to examine migration events and alteration processes that have affected the composition of oil. The big advantage of using FIs is that the oil is physically isolated from the main pore system of the reservoir rock. Therefore, subsequent events in the reservoir such as loss of charge, water-washing, biodegradation and drilling do not affect the composition of the inclusion oil. In the last decades a full range of hydrocarbons was measured from inclusions, including low molecular weight hydrocarbons, n-alkanes, aliphatic biomarkers, hopanes and steranes, and aromatic hydrocarbons using gas chromatography–flame ionisation detection (GC–FID) and gas chromatography–mass spectrometry (GC–MS) (George et al, 2007). However, complex mixtures like inclusion oils are not only composed of non–polar aliphatic and aromatic hydrocarbons but also of organic compounds containing nitrogen, sulfur, and oxygen (NSO compounds) possessing functional groups that lead to an increased polarity. Fourier transform-ion cyclotron resonance-mass spectrometer (FT-ICR MS) affords ultra-high mass accuracy and resolving power, making it possible to identify molecular formulas in these complex organic mixtures and to resolve thousands of compounds (especially polar and high molecular weight compounds not accessible before) in the inclusion. In this study FI samples from the Lower Saxony Basin (NW, Germany) have been chosen for a first method development, including a sample clean-up using solvents of different polarity and sonication to gain procedural blanks before the inclusions are cracked and the inclusion oils are extracted. Here attention to details is essential to avoid contaminations for a successful analysis of inclusion oils. GC-MS and FT-ICR MS analyses will be run to characterize the organic inventory in FI extracts. Based on these data, the suitability of the chosen methodology will be evaluated, and gained geochemical information from the FI oils will be presented. Reference George S. C., Volk H. and Ahmed M. (2007) Geochemical analysis techniques and geological applications of oil-bearing fluid inclusions, with some Australian case studies. Journal of Petroleum Science and Engineering, 57, 119–138.
Estimating biophysical vegetation parameters on agricultural fields using multi-temporal Sentinel-1 data

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A sustainable use of arable land and natural resources to ensure food security is of high importance. With the help of satellite images, information about the plant status can be obtained which support farmers in their field management strategies. Optical remote sensing data provide useful information to derive vegetation parameters, but their availability is often limited due to clouds. The ESA satellite mission Sentinel-1 provides radar images with a high temporal resolution which are much less influenced by weather conditions compared to optical data. The aim of the study is to investigate how Sentinel-1 radar images can fill data gaps in optical remote sensing data to estimate vegetation parameters even in short-term phenological growth stages. The study focuses on the parameter estimation based on a statistical approach of linear regression modeling. In-situ field measurements of wheat and barley fields taken in the vegetation period 2017 serve as ground reference data. Five biophysical crop parameters including plant height, crop coverage, leaf area index (LAI), wet biomass and dry biomass were correlated with Sentinel-1 scattering coefficients in VV and VH polarization as well as with their combinations. The capability of simple linear regression models to estimate the aforementioned parameters are not satisfactory in general with coefficients of determination ($R^2$) around 0.3 and less. However, moderate $R^2$ have been observed between different scattering coefficients and single vegetation parameters like plant height, dry biomass or LAI after taking into account certain influencing factors. Another focus of the study is the analysis of factors influencing the regression results to improve the models. The sensor pass direction, the local incidence angle, the soil moisture, the phenological stage, the study area and the value extraction method are factors that are possibly influencing the model performance. Furthermore, the exclusion of outliers and the application of nonlinear simple models is investigated.
High resolution Seismic image of Central Alps derived from Local Earthquake Tomography (LET)

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2.2 - Geophysical Deep Sounding

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Understanding the processes that governed the formation of various structures in the Alps requires investigation of seismicity in the region on the one hand, and high resolution structural images down to the base of the crust, and possibly to the mantle, on the other hand. Many previous studies invoked various methods to provide images down to the Moho, but they did not capture the 3D lithospheric structure sufficiently to resolve the main kinematics at the Central Alps and their relationship to crustal faulting and seismicity. A challenge faced by all previous passive seismic studies in the Alps is the sparse local seismicity and the coarse permanent station networks. As part of the international AlpArray initiative and within the DFG-Priority Programme “4D-MB” we aim to derive a high-resolution 3-D model (Vp, Vs, Qp, Qs) of the Central Alps by applying local earthquake tomography (LET). The seismicity recorded by national and international earthquake catalogs from the Alpine region shows moderate activity with low to medium magnitude events down to 20 km. The dense local seismic network (SWATH-D) temporarily deployed in the Central and Eastern Alps consists of 150 seismic stations with a remarkable close station spacing of ∼12 km. This dense deployment will complement the larger scale AlpArray Backbone network. Combining the new seismic models and the precise hypocenter relocations will enable us to resolve the fine structures in the target area. The objectives in this study, accordingly, are to collect all the available seismic data in the region and implement event detection, phase picking, accurate hypocenter localization and seismic velocity and attenuation tomographic inversion. The new models and images will then be interpreted in the interdisciplinary context within the Priority Programme. We present the current status of this project which has just started.
Hydraulic-Mechanical Characterization of Shear Fracture Permeability

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6.2 - Geothermal Energy Systems

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The permeability of geothermal reservoirs is often low and requires enhancements techniques such as hydraulic stimulation. The generated fractures were for a long time described as tensile. However, other fracture mechanisms, such as shear fracturing, is a common fracture mechanism for the stimulation in geothermal reservoirs. We aim to better understand permeability evolution of shear fractures at elevated effective pressures. Therefore, an integrated experimental and numerical approach is used to better characterize the mechanisms that control fracture permeability evolution of shear fractures and tensile fractures with shear displacement. The experimental approach comprises different flow-through experiments with cylindrical rock samples in a MTS tri-axial compression cell, allowing for continuous permeability measurements at in-situ reservoir conditions. To measure permeability of a flow-parallel shear fracture with increasing displacement at varying effective pressures, a modified Punch-Through Shear (PTS) test setup is used. Samples with a pre-existing tensile fracture in a setup with hemi-circular end caps is used to create asymmetric loading conditions and a consequent shear displacement. CT scans of the tested samples are made after the experiment to characterize the geometry, roughness, and aperture change of the fracture. The numerical approach uses self-affine artificial fractures and natural fracture surfaces obtained from photometric surface scans and CT scans of the laboratory samples to generate 3D fracture models. Stoke flow simulations in Comsol are used to characterize permeability, as well as the velocity and pressure distribution in rough fractures. Shear fracturing can increase the permeability. However, consequent shear displacement under elevated effective stress leads to almost no increase of permeability and effective pressure cycling can reduce permeability marginally. The cubic law, which assumes that the flow in fractures can be approximated by two parallel plates, shows limitations for rough fractures and overestimates the fracture permeability especially for small apertures.
Hyperspectral drill core analysis and mineral detection

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1.4 - Remote Sensing

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An ever-growing depository of drill cores from different projects in the scientific and industrial community is calling for a time-efficient qualitative mineral analysis which also allows for a high turn-over rate. This includes the scanning of core boxes and obtaining surface data of a large quantity of drill cores as well as the in-depth analysis of round core by unrolling their surface and creating a 360° hyperspectral survey. Both has been done exemplarily on drill cores from the Seve Nappe complex, Sweden. In the course of the Collisional Orogeny in the Scandinavian Caledonides Project (COSC), a 2.5 km drill core was conducted. A small number of core samples ranging from depth of 1682 m to 2469 m were analysed, utilizing the hyperspectral imaging system “HySpex”. HySpex combines the range of the VNIR (450 nm – 1000 nm) and the SWIR region (1000 nm – 2500 nm) in two instruments. In order to verify the mineral analyses for the 360° measurement of a core surface, laser induced breakdown spectrometer (LIBS) measurements of a core were compared directly and pixel-wise to the HySpex measurements. The hyperspectral imagery allowed for a resolution of 0.22 mm/pixel which resembles the resolution of the LIBS measurements. An un-split core sample from 1682 m was used to develop an approach of a hyperspectral measurement of the un-rolled, complete 360° core surface. The measurements of the whole core surface with overlapping surface frames amounted to 22 h/m of core and resulted in a hyperspectral mosaic of the core mantle surface. Relative to the approximately 550 h needed to measure 1 m of core with the LIBS, the hyperspectral method seems fair and feasible. The succeeding mineral mapping with EnGeoMap proved to be very precise when detecting the abundance of single minerals, when mapping multiple minerals, a bias towards a few minerals was found. This bias due to mineral-dependent fit value thresholds of the algorithm has to be investigated further in the future. When applying EnGeoMap, it proves a valuable tool to evaluate mineral content and their spatial distribution over the course of a drill core, especially to highlight changes in material assemblages. This approach could be interesting to apply to different sample kinds in creating whole surface analyses.
Methane emissions from arctic permafrost - towards closing the gap between bottom-up and top-down approaches using aircraft measurements

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Arctic permafrost stores about twice as much carbon than currently stored in the atmosphere. Part of the carbon is emitted into the atmosphere as the strong greenhouse gas methane. However, the amount of methane currently released from arctic permafrost landscapes is not yet sufficiently assessed. Particularly, there are large discrepancies between top-down and bottom-up estimates of methane emissions, partly because the methods operate with different spatial resolutions and coverage. This causes large uncertainties when extrapolating local or regional estimates to the circum-Arctic and does not provide a solid baseline for estimating future methane emissions. The recent development towards aircraft measurements of methane fluxes has the promising advantage that these measurements cover entire regions while providing data at relatively high spatial resolution, dependent on the instrumentations and methods used. As a first step in seeking to assess whether and how aircraft measurements can bridge the gap between top-down and bottom-up estimates by providing regional measurements, we compare estimates from different aircraft data sets, by addressing the following questions: 1. How do the total emissions and spatial patterns derived from independent aircraft campaigns differ? 2. Do the environmental drivers selected to create the methane flux maps overlap? Or rather, can the same environmental drivers be used to create similar flux maps based on different data sets? Our study approaches the challenge towards bridging the gap by using two aircraft data sets from the North Slope of Alaska: First, methane flux measurements from the Airborne Measurements of Methane fluxes (AIRMETH) campaign, and secondly, methane fluxes based on aircraft data from the Carbon in Arctic Vulnerability Experiment (CARVE) campaigns. From the AIRMETH campaign, the methane fluxes were calculated via the eddy-covariance technique and have a resolution of 100 m, whereas from the CARVE data methane emissions were derived via inverse modelling resulting in a spatial resolution of 0.5°. The fluxes are compared to eddy-covariance measurements from well-established towers located on the North Slope of Alaska. We found that the overall monthly emissions from North Slope derived from the two aircraft data sets were in same order of magnitude and did not differ significantly. The spatial patterns of the emissions were similar with the AIRMETH data having higher emissions in the northern part and CARVE in the southern part and matched well the fluxes measured at the tower locations. Our results suggest that proxies of soil moisture and temperature are relevant drivers on all scales and could possibly be used to serve as bridge. Using those drivers, both approaches led to more similar spatial patterns. It seems promising that, like described for annual cycles of methane fluxes, proxies of temperature and soil moisture can be used as drivers to create similar regional maps from independent aircraft data sets. Thus, using this set of drivers across the scales might enable us to combine local and regional measurements to bridge the gap between top-down and bottom-up approaches and to derive both annual cycles of methane fluxes on a regional scale and to derive fluxes in areas that have not been covered by measurements.
The effects of regional fluid flow on the deep thermal field - a case study from the Federal State of Hesse (Germany)

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Geothermal energy utilization for electric power generation was planned in the Federal State of Hesse at two sites. The first one in the northern part of the Upper Rhine Graben (south Hesse) has been drilled in 2016 but flow rates and temperatures were well below expectations. The reasons for local reduction of porosity and permeability in the reservoir compared to what is known from outcrop analogue studies and other sites in the middle Upper Rhine Graben, are still a matter of discussion and illustrate the need for a possibility to predict such processes and thereby minimize the drilling risks. The aim of this study is to understand the influence of regional hydrothermal processes on the local geothermal configuration of reservoirs. We address the question if and how the regional fluid and heat flow influences the local reservoir behavior and if we can improve predictions. Therefore, a 3D structural model of Hesse is used as a base for coupled 3D hydrothermal simulations of the deep fluid and heat transport. The model is 6 km deep and the processes are simulated with the commercial software FEFLOW®. As the model boundary is following the Hessian border and crossing the Upper Rhine Graben, lateral boundary conditions for fluid flow were extracted from an uncoupled fluid flow model covering the whole Upper Rhine Graben. First results show higher temperatures in southern Hesse (northern part of the Upper Rhine Graben) and lower temperature in northern Hesse (Hessian Depression). Moreover, the simulations show that the regional flow is divided into two regions. In the southern part of Hesse Rotliegend sediments of the Saar-Nahe basin and up to three kilometers thick Cenozoic deposits of the Upper Rhine Graben build a thick aquifer. In the northern region, the Buntsandstein of the Hessian Depression forms an up to 1.4 km thick aquifer. In the southern region, thermal water is uprising forming local geothermal anomalies and resulting high temperatures provide favorable conditions in target horizons in depths below 1.5 km for geothermal utilization. In contrast, in the Hessian Depression groundwater recharge causes reduced temperatures in the target horizons which are too low for geothermal power generation. In further work local more detailed models covering only the southern part of Hesse, will help to predict locations or settings favoring upwelling of deep hot water, which are the target for geothermal exploitation. The regional model of Hesse which is presented here will provide the necessary boundary conditions.
Phase separation of a single magmatic fluid as a mechanism for the formation of tin-tungsten deposits

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3.1 - Inorganic and Isotope Geochemistry

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Tin (Sn) and tungsten (W) mineralization are commonly associated with each other and occur mainly in relation to highly evolved granites. Mineralization styles are highly variable, indicating different mechanisms for ore formation. The Sn-W-Li deposit in the roof zone of the Zinnwald granite is associated with Sn-bearing greisen and sub-horizontal veins containing economical contents of cassiterite and wolframite. The relation between the contrasting mineralizations remains elusive. We analysed fluid inclusions from samples of the German part of the deposit using conventional, infrared-microthermometry and LA-ICP-MS. The most common primary FI in the quartz veins show homogenization temperatures (Th) between 360°C and 380°C and high variability in salinity (1–8 wt.% NaCl eq.). IR microthermometry of fluid inclusion in ore from the vein reveal lower Th but higher salinities (12 wt.% NaCl eq.). In contrast fluid inclusion assemblages in greisen have similar Th (360–380°C) to the vein quartz and salinities between 5 and 8 wt.% NaCl eq. Few quartz vein samples contain boiling assemblages of brine (up to 35 eq.w(NaCl)) and vapor-rich inclusions (Th = 300-340°C) LA-ICP-MS data show that all elements required for forming a Sn-W deposit are included in the hydrothermal fluid. The results suggest that ore formation is controlled by two processes: 1) fluid rock interaction during greisen formation and 2) boiling and the loss of HCl leading to ore precipitation in the veins. The results further emphasize the importance of fluid inclusions in ore minerals because they can document fluid processes that are absent in the fluid inclusion record of gangue minerals.
Microbiological characterization of initial soils on James Ross Island, Maritime Antarctica

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The interaction of biotic and abiotic processes remains one of the fundamental questions in ecosystem research. So far, only few studies exist for polar environments that integrate pedogenic and microbiological research. Due to the absence of vascular plants and burrowing animals, the ice-free areas of James Ross Island offer the exceptional opportunity to improve our understanding of the impact of microbial processes on soil formation in a pristine laboratory. Soil profiles at St. Martha Cove (SMC) and Brandy Bay (BB) on James Ross Island were sampled. These study sites are characterized by similar topographic positions and parent material. The soil samples were investigated through an interdisciplinary approach combining pedological, geochemical and microbiological methods. Prokaryotic communities were characterized with qPCR and Illumina 16S rRNA gene sequencing. Microbial abundances showed a similar trend for both sites with comparable 16S rRNA gene copies in the topmost layer and a substantial decrease with depth. Both profiles were dominated by bacteria and only the upper layers of SMC showed higher proportions of archaeal OTUs. Increasing relative abundances of OTUs related to Acidiferrobacteraceae, potential sulfur and/or iron oxidizing bacteria, were observed in deeper layers of BB and SMC. Multivariate statistics revealed that differences in grain size distribution, and the amount of organic and inorganic carbon have the highest influence on the microbial community structure and explain 52.2% of the variation. The present study gives a first insight in the state of microbial life in initial soils of Antarctica and could help in understanding the future development of Antarctic soil environments and the response of microbial communities to a changing climate.
The Hämmerlein skarn hosted polymetallic deposit, western Erzgebirge, Germany: Two phases of mineralization – two Sn sources

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3.1 - Inorganic and Isotope Geochemistry

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The Hämmerlein polymetallic skarn deposit of the western Erzgebirge is hosted in schists and gneisses which reach their metamorphic peak conditions during the Variscan orogeny at ~340 Ma. The deposit is located in the vicinity of one of the most voluminous granites of the Erzgebirge, the Eibenstock granite, which intruded the metamorphic units at ~320 Ma. As skarn deposits forms by magmatic fluids, which carry the ore metals that react with carbonate rocks, the Eibenstock granite is generally thought to be the source of metals for the Hämmerlein deposit. The age of the skarn has been bracketed by the multi-mineral Rb-Sr isochron age of the gneiss, ~340 Ma, and the end of the ductile deformation of both gneiss and skarn, which in the Erzgebirge happens at ~330 Ma. This means that the skarn formed well before the emplacement of the Eibenstock granite. Furthermore, ~340 Ma old skarn minerals (garnet, amphibole, and pyroxene) that formed during regional metamorphism contain up to 0.45 wt% Sn. This implies that tin was remobilized and available for being incorporated into the skarn calc-silicate minerals already during regional metamorphism. The main tin ore mineral in the Hämmerlein skarn is cassiterite that forms in late cassiterite-chlorite-fluorite assemblages. The very radiogenic Sr isotopic signature of these late assemblages requires that a significant time (>15 Ma) had elapsed between formation of the skarn and its retrogression. This means that the cassiterite-bearing secondary mineral assemblages are related to a second event, most likely the Eibenstock granite intrusion rather than retrogressing directly after skarn formation. Mass balance indicates that tin available for cassiterite formation cannot be derived from altered primary minerals. Therefore, there must be a second, more important, source of tin. This younger Sn-addition may be related to the emplacement of the Eibenstock granite that also provides tin for numerous greisen mineralizations.
Micro-seismicity induced during a geothermal soft stimulation experiment at Pohang, South Korea: Preliminary results

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4.2 - Geomechanics and Rheology

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Geothermal energy can contribute to the enhancement of renewable and green energy sources, particularly in crustal regions with large heat flow. However, the stimulation of geothermal reservoirs implies the occurrence of induced seismicity and consequently increases seismic risk. To mitigate the occurrence of induced seismicity, a soft stimulation technique based on cyclic injection schemes was developed. This technique was applied at the Pohang Enhanced Geothermal System (EGS) site in South Korea during August 7th-14th, 2017. A major goal of this in-situ experiment was to limit the magnitude of induced seismic events to a target threshold of M2. The experiment was monitored by a seismic system consisting of a borehole chain of 17 geophones as well as 6 surface seismometers and 9 shallow and deep borehole sensors distributed within a radius of 7 km around the monitoring and injection wells PX1 and PX2, respectively. A traffic-light system was set on-site to reduce the injection rates based on the peak ground velocity (PGV) at one of the surface stations. In a first step, an initial catalog with 53 automatically triggered events and locations were used. We refined the catalog by a manual picking of P- and S-wave onsets on three-component seismograms. The detected seismicity appears to have very low signal to noise ratio in most surface and downhole stations, and thus we could only pick all events and phases using the borehole geophone chain. The picked P- and S-wave arrival times were used to improve the hypocenters of the 53 events applying an absolute location method. For estimating their magnitudes, we applied a spectral fitting technique to the events. We focused on S-wave onsets as the most energetic part of the waveforms. The observed ground displacement spectra were fitted to a point-source model spectrum. We inverted for the seismic moment Mo by optimizing the resulting cost function and then estimated the moment magnitude Mw from the seismic moment. Results for the hypocenter determination show that a good control over the source-station-distance was achieved, but the azimuthal control was limited due the availability of only chain channels displaying very similar azimuth. The events appear to be located around the monitoring well, mainly placed in a depth of 4 - 4.7 km. The spectral fitting provided moment magnitudes Mw in the range [-0.1, 1.9], which successfully confirmed the goal of the experiment. Further data refinement will improve these initial results. Additionally, further source parameter estimations as well as the seismic analysis of more triggered events will follow.
Performance assessment of multi-GNSS precise velocity and acceleration determination over Antarctica

Min Li

1.2 - Global Geomonitoring and Gravity Field

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GNSS had played an important role in precise velocity and acceleration determination over Antarctica since the end of 1980s. However, the satellites coverage and the ground environment in polar region make positioning quite different from low-latitude areas. Also conventional Differential GPS techniques (DGPS) based velocity and acceleration method named ‘DVA’ may be difficult to be implemented as there is a sparse distribution of reference stations over Antarctica. Thus, in order to overcome the baseline limitations and to obtain high accurate and reliable velocity and acceleration estimates for airborne gravimetry, a network-based velocity and acceleration determination approach named ‘NVA’, which introduces a wide network of stations and is independent of precise clock information as it estimates satellite clock drifts and drift rates ‘on-the-fly’, is applied. This method has been originally discussed in Salazar et al. (2011). Here its performance for velocity and acceleration determination over Antarctica is fully exploited but using GPS, GLONASS, Galileo and BeiDou observations. Additionally, a standalone receiver based method named ‘SVA’, which requires precise clock information, is also implemented for comparison. A GPS+GLONASS+Galileo+BeiDou four-system model is presented and proper weighting of different types of observations is investigated. The results show that compared to an equivalent weight ratio (EWR), it is more appropriate and efficient to assign the weights using a posteriori weight ratio (PWR). During static tests and a real flight experiment over Antarctica, it turned out that the NVA method yields more robust results than the SVA and DVA methods when applied to a wide area network. Moreover, the addition of GLONASS, Galileo and BeiDou systems can increase the accuracy of velocity and acceleration estimates by 39% and 43% with the NVA compared to a GPS-only solution when using 30-second sampling interval data. For the purpose of airborne gravimetry, the L1 observable is suggested for velocity and acceleration determination over Antarctica because of its lower observation noise. However, the ionosphere is still present in L1, it will show up in the adjusted velocity. An ionospheric drift will cause a biased velocity. If it is felt that this effect should not be present at all, the ionosphere-free linear combination (LC) observation is preferable.
Integrity monitoring of geothermal wells using fiber optic distributed sensing techniques

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6.2 - Geothermal Energy Systems

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Borehole integrity for high temperature wells is a fundamental challenge in the successful and sustainable utilization of geothermal energy. Information about the quality of casing and cement is mainly available from logs which only produce data at the moment of measurement and require a risky run in hole with logging tools. Installing a fiber optic cable permanently behind casing bypasses these downsides. It can help to monitor the performance of the well in real-time and serve as an early warning system. That is because each location of the fiber conveys information about its temperature and mechanical stress state when interacting with a laser pulse which is sent through the fiber. This work shows field data from a fiber optic installation and compares the results to conventional borehole measurement equipment during the completion of a geothermal well. It was found that the mechanical strain acting on the fiber is in accordance with results from conventional downhole logging tools for density measurements. Moreover, long-time observation of the strain response reveal an ongoing movement of subsurface material (sagging and compaction of filter gravel pack). During later cementation of the annulus, a dynamic strain signal was measured on the interface between the fresh water spacer and viscous cement. It will be discussed to what extent this signal can be used to derive rheological parameters of the cement slurry. Experiences from this measuring campaign forms the basis for subsequent strain measurements during harsher temperature and strain conditions.
Application of a model for point-wise prediction of stream flow statistics using climatic and geomorphologic data to Taiwan

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5.5 - Earth Surface Process Modelling

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Fluvial erosion controls the shape of many mountain belts. Much effort has been put in understanding how climate affects river discharge and consequently fluvial erosion. In particular, it is important to develop a better understanding of the link between rainfall variability and mean, and discharge variability and mean in order to build predictable models of long-term geomorphic evolution of mountain belts, but also to predict the magnitude and frequency of natural hazards. Most existing models rely, however, on the assumption that rainfall characteristics are uniform over a given catchment. This is clearly not the case for many mountainous catchments which are affected by orographic effect or for catchments much larger than the average storm size. The main focus of the work presented here is to overcome these limitations, and to improve current models of the relationship between rainfall and discharge characteristics. Ultimately, our work can be used to predict how these forcings affect erosional processes characterized by a threshold. We have used the same stochastic, analytical model as Deal [1] and developed by Botter et al [2]. An analytical expression, used in the model for the prediction of discharge probability density function, is defined by four physically based parameters that are the mean rainfall depth, the frequency of flow producing rainfall events, the coefficient and the exponent describing the discharge recession equation \( \frac{dQ}{dt} = -KQ^a \), which are estimated using only climatic and geomorphologic data from Taiwan. We have also used the geomorphic recession flow model of Biswal and Marani [3] further improved by Doulatyari et al [4] that uses digital elevation maps to estimate the geometry of the drainage network and its evolution through time to compute discharge variability at various points along the drainage network. We show, using this model, that we can predict with reasonable accuracy discharge variability observed at various gauging stations in a catchment affected by a strong orographic gradient. We are currently working on applying this method to other areas.

Literature

Geomagnetic paleosecular variations spanning from 40 to 20 ka from Black Sea sediments - implications for the Mono Lake excursion

Jiabo Liu

5.2 - Climate Dynamics and Landscape Evolution

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The Mono Lake excursion at around 35 ka, characterized by virtual geomagnetic poles (VGP) migrating to low latitudes on the northern hemisphere, has been documented from an increasing number of sites all over the globe. However, the pattern of Earth’s magnetic field behavior during the Mono Lake excursion is not comprehensively described, since paleomagnetic records are often not detailed enough in order to precisely analyze the geomagnetic field geometry during the course of this excursion. A full-vector PSV record (inclination, declination, relative paleointensity) between 40 and 20 ka, covering the Mono Lake excursion, could be reconstructed from seven Black Sea sediment cores. The Age models are based on radiocarbon dating and tephrochronology. Further age constrains were achieved by tuning IRD (ice rafted debris) counts and XRF logs (mainly Ca/Ti ratio) as proxies for Dansgaard-Oeschger warming events, to the oxygen isotope record from Greenland ice cores (NGRIP). The PSV records of Black Sea sediments were then stacked by using 100-year bins. The Mono Lake excursion in Black Sea PSV records, centered at 34.5 ka, is characterized by low relative paleointensities and anomalous paleomagnetic directions. At about 25 ka, another low relative paleointensity episode was also detected, yet without remarkable paleomagnetic directional variations. On the other hand, inclinations were fairly shallow at about 30 and 27 ka, respectively. However, relative paleointensities are not noticeably low. Furthermore, after the Mono Lake excursion, the declinations were slightly oscillating around the expected declination from a dipole field at the Black Sea site. The VGP’s during the Mono Lake excursion, calculated from Black Sea data, migrated from the Alaska, via Siberia, to the north of India, then west-northward cross the central Asia to the Greenland. Thus, the VGP path during the Mono Lake excursion depicted a clockwise looping and migrating within the Eurasian continent. And, the Black Sea record also demonstrates the revival of a dipole-dominated geomagnetic field after the Mono Lake excursion.
Microbial distribution, abundance and activity in a dry CO2 degassing mofette in Hartoušov, NW Bohemia

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The Cheb Basin (CZ) is a shallow neogene intracontinental basin filled with fluvial and lacustrine sediments. The central and northern parts of the seismic active rift are characterized through diffuse degassing of mantle-derived CO2 in form of so-called mofettes. The Hartoušov mofette field shows the highest CO2 flux (>99%) and soil gas concentration among those mofettes. The present study aimed to characterize the influence of elevated CO2 concentrations on the geochemistry and microbial community/processes. Two 3 m drillings were performed, one located in the centre of the degassing structure and the other 8 m away served as an undisturbed reference. The sites were compared in terms of their geochemical features, microbial abundances, community structures and methanogenic activity. The results highlight the strong impact of elevated CO2 concentrations and associated side effects on microbial processes. Illumina MiSeq sequencing of the 16S rRNA genes and multivariate statistics revealed that the pH strongly influenced species distribution and explained around 35.3% of the variance between mofette and the undisturbed site. Accordingly, acidophilic microorganisms (e.g. Acidobacteriaceae and Acidithiobacillus) showed a much higher relative abundance in the mofette than the undisturbed site. Additionally, genera potentially linked to carbon fixation were found in deep sediments of the mofette. Activity tests performed with sediments from both sites showed that the potential microbial methane production rate is significantly higher in the mofette. We demonstrated that an increased availability of hydrogen (occurring during seismic events) can trigger methanogenic activity. The present study provides insight into microbial life and bio-geo interactions in CO2-dominated habitats such as mofettes.
How do changes along the risk chain affect flood risk?

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The interaction of physical and socio-economic systems causes flood risk. Therefore, the assessment of flood risk ideally considers the whole flood risk chain, from the atmospheric processes, through the catchment and river system processes to the damage mechanisms in the affected areas. Within a given flood risk system, a multitude of influences can occur with potential effects on the characteristics of the flood risk. This study uses the flood-prone Mulde catchment in Germany as an example to quantify and discuss the state of knowledge about the sensitivity of flood risk to changes along the risk chain. The main goal of this study is to provide a comprehensive sensitivity analysis considering changes in all risk components, i.e. changes in climate, catchment, river system, land use, asset values and vulnerability. The flood risk is computed using the Regional Flood Model (RFM), which is based on a continuous simulation approach, including rainfall-runoff, 1D river network, 2D hinterland inundation and damage estimation models. To understand the sensitivity of flood risk to the drivers in this risk chain, our approach is to use a logic tree which combines all possible combinations of components. For each component, we defined three scenarios, a baseline scenario and two symmetric change scenarios. In total we evaluated 729 scenarios. As risk indicators, results are expressed in terms of expected annual damages (EAD) and risk curves. The results show that components like changes in dike and/or vulnerability, which have not gained a lot of attention so far, may outweigh changes in components such as climate and/or land use which are mostly considered as the main drivers of flood risk.
Biomarker and NSO compound characterization of crude oils from the Northern Western Desert (Egypt) – A window into source rock-oil correlation

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Comprehensive organic geochemical studies were carried out on 280 cutting samples from 7 wells covering the Jurassic-Cretaceous interval of the Shushan Basin, and on 12 crude oil samples from productive Cretaceous reservoirs in the Shushan, Abu Gharadig and Dahab/ Mireir Basins from the North Western Desert in Egypt to establish oil-source correlations. The conceptual approach is based on the investigation of the petroleum potential of organic-rich sediments and the comparison of these sediments with the oils with respect to different elemental, molecular and isotopic parameters. The investigations include different analytical techniques and instruments in order to address different compound classes, such as Gas Chromatography-Flame Ionization Detection (GC-FID), Gas Chromatography-Mass Spectrometry (GC-MS), Open-Pyrolysis Gas Chromatography (Open-Py-GC), Rock-Eval Pyrolysis and Fourier Transform-Ion Cyclotron Resonance-Mass Spectrometry (FT-ICR-MS) in combination with an electrospray ionization (ESI) source run in the negative-ion mode. The Jurassic Khatatba and Yakout Formations contain organic-rich intervals with good to very good hydrocarbon potential with S2 above 5 mg/g TOC. These intervals are dominated by thermally mature type III and II/III kerogen. Tmax values range from 424°C to 458°C and vitrinite reflectance from 0.58% to 1.01% R0 indicating an immature to late oil maturity. In contrast, the sediments of the Cretaceous interval have lower thermal maturities characterized by Tmax data ranging from 415°C to 444°C and vitrinite reflectance values between 0.50% and 0.73% R0. Sediments from the Jurassic have the potential to generate gas and condensate, but the organic-rich intervals of Khatatba Formation have the ability to generate oils classified as paraffinic-naphthenic-aromatic (P-N-A) oils. Among the Cretaceous sediments almost all sections have the potential to produce (P-N-A) oil. The n-alkane distributions of the crude oil samples are dominated by long chain n-alkanes indicative for higher plant contributions while biodegradation seems to have not affected the samples. The oil samples are paraffinic-naphthenic medium to light gravity oils of 32 to 52 API Gravity, where the percentages of saturated hydrocarbons are roughly above 45%. The pristane/phytane (Pr/Ph) ratios of Shushan oils are above 3 suggesting shales with terrigenous organic matter input as source rock, whereas they range from 1.41 to 2.14 in Dahab/Mirier and Abu Garadig oils indicating a mixed marine/terrigenous organic matter input. Different biomarker ratios based on steranes and hopanes as the 22S/(22S+22R) ratio of C31-homohopanes showed that the oils were formed from thermally mature organic-rich shales. Another maturity indicator, the 18α(H)-22,29,30-trinorhopane/Ts+17α(H)-22,29,30-trinorhopane (Ts/Tm) ratio, displays decreased values for especially the Shushan oils (0.31 – 0.66), which might not reflect lower maturity but an increased shale content of the source rock 0.31 - 0.66. The FT-ICR-MS results of the acidic NSO compounds show that the crude oils from the North Western Desert are dominated by oxygen-containing compounds with abundances ranging from 60 up to 89 % total monoisotopic abundance (TMIA). O1 compounds predominate in the class of oxygen-containing compounds and make up 50 to ~70% TMIA. The relative high abundance of O1 compounds is strongly attributed to early maturity stage charging. The correlation between Shushan and Abu Gharadig oils displays that these oils resemble chemically and that their composition was controlled by maturity.
Imaging Beneath the Alps with Distant Earthquakes

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Teleseismic waves from distant earthquakes can be used to image structure deep in the Earth with the Receiver Function technique. By applying this method to seismic stations in the Alps, subducting slabs can be imaged and then linked to surface exposures of exhumed crust. By accurately imaging these slabs the understanding of the subduction history of the Alps can be improved. The temporary SWATH-D deployment (supplementing the AlpArray seismic network) is currently recording earthquakes that will be processed using this technique.
Effect of different loading conditions on the nucleation and development of shear zones around material heterogeneities

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4.2 - Geomechanics and Rheology

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Rock deformation at depths in the Earth’s crust is often localized in high temperature shear zones, which occur in the field at different scales and in a variety of lithologies. The presence of material heterogeneities is known to be a cause for shear zones evolution, but the mechanisms controlling initiation and development of localization are not fully understood, and the question of which loading conditions are most favourable is still open. To investigate the effect of boundary conditions on shear zone nucleation along heterogeneities, we performed torsion experiments under constant twist rate (CTR) and constant torque (CT) conditions in a Paterson-type deformation apparatus. The sample assemblage consisted of copper-jacketed Carrara marble hollow cylinders with one weak inclusion of Solnhofen limestone. CTR experiments were performed at maximum bulk strain rates of 1.8-1.9*10^{-4} s^{-1}, yielding shear stresses of 19-20 MPa. CT tests were conducted at shear stresses between 18.4 and 19.8 MPa resulting in shear strain rates of 1-2*10^{-4} s^{-1}. All experiments were run at 900 °C temperature and 400 MPa confining pressure. Maximum bulk shear strains (\gamma) were ca. 0.3 and 1. Strain localized within the marble in front of the inclusion in an area (process zone) where grain size reduction is intense and local shear strain (estimated from passive markers) is up to 10 times higher than the applied bulk strain, rapidly dropping to 2 times higher at larger distance from the inclusion, independent of the applied loading conditions. The evolution of microstructural parameters such as average grain size and grain orientation spread (a measure of lattice distortion) within the process zone, as determined by electron backscatter diffraction analysis, shows only minor differences between loading conditions. Our results suggest that loading conditions do not substantially affect material heterogeneity-induced localization in its nucleation and transient stages.
Among the metals present in contaminated soils and groundwater, Nickel (Ni) can be especially problematic due to its relatively high solubility and toxicity. Previous studies evidenced that green rust (GR) can incorporate Ni²⁺ into its structure and, therefore, remove it permanently from water in anaerobic environments. However, the efficiency of the immobilization process and how the incorporation of Ni affects GR properties is still unknown. To evaluate the potential of GR as a geomaterial for Ni removal, we performed a series of co-precipitation experiments of GR in presence and absence of Ni at different concentrations. Results indicate that the efficiency of removal increases with increasing initial Ni concentration. In addition, the depletion of Ni in solution continues over time, suggesting that further crystal growth and surface adsorption can enhance the total removal capacity. The analysis of GR particles by TEM imaging and XRD suggests that both crystallinity and particle size might decrease with increasing Ni concentration as a result of a contraction of the crystal lattice. However, because of the high polydispersity of the particles, the quantification of these two parameters was not possible. In conclusion, GR co-precipitation can be an effective method to immobilize Ni²⁺ from polluted anoxic groundwaters and to modify GR properties, which will need to be considered in future studies to evaluate the effect of metal doping in GR reactivity.
Large scale flood risk analysis for rice cultivation in the Vietnamese Mekong Delta

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Flooding is an imminent natural hazard threatening deltas as e.g. the Mekong Delta. Whilst, delta residents might benefit from normal flood events (commonly perceived as good flood in the Mekong Delta), extreme events may result in delta wide fatalities and economic losses, as e.g. observed during the floods in 2011 and 2000. The probabilities of occurrence of such devastating flood events are likely to increase in the future in the Mekong Delta due to climate change and sea level rise. Thus, estimation of agro-economic risk imposed by such flooding event is valuable information for flood management. In this study, we develop a model to measure direct losses of rice crops in the delta for flood events with 10 yr, 20 yr, 50 yr and 100 yr return period. First, the peak discharge and flood volume at the apex of the Mekong delta (i.e. Kratie) were derived from a bi-variate flood frequency analysis. A quasi 2D hydro-dynamic model was used to derive flood hazard maps for the delta. The agricultural flood risk was calculated by examining the temporal relationship between rice crop harvest time, estimated from the time-series of enhance vegetation index (EVI) from MODIS data in 2011, and the simulated inundation maps. As results, delta-wide maps of rice losses by flooding at each flood frequency are presented as well as the region with the highest risk. These risk maps may serve as a guidance for the state government to allocate budget for flood prevention as well as flood alleviation measures.
Classifications of acoustic emissions from hydraulic fracturing experiments at the Åspö Hard Rock Laboratory (Sweden): From false event detection to network-based waveform clustering

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2.6 - Seismic Hazard and Risk Dynamics

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An in-situ, multi-stage hydraulic fracturing (HF) experiment was performed at the Åspö Hard Rock Laboratory (Sweden) at a depth of 410 m to compare hydraulic fracturing growth and induced seismicity under controlled conditions for different fluid-injection schemes (continuous, progressive, pulse injection). Acoustic emission (AE) activity was recorded with a near field network of 11 piezoelectric sensors installed around a horizontal, 28m long bore hole. The sensor’s highest sensitivity is in the frequency range of 1 to 100 kHz, but sampling rates were extended to 1 MHz. We focus on one of these HF experiments (HF2) within crystalline rock (Åvrö granodiorite). We use a combination of advanced waveform based techniques to detect and characterize massive high-frequency AE signals. We first apply a signal detection algorithm to the continuous waveforms, using a delay-and-stack approach. Then, an automated signal classification algorithm based on Hidden Markov Models is used to discriminate between AEs related to the fracturing process and false detections, such as electronic or production-related noise. The procedure results in a catalog of over 4000 AEs. The detected events were also classified manually. We found that the automated classification procedure recognizes 96% of the manually classified AE events in HF2. Hence, the procedure is accurately tuned to be applied to further HF experiments. The AEs are subsequently located using an automated full waveform algorithm based on the stacking of waveforms and coherence analysis. The hypocenters are spatially clustered in a planar region, resembling the main fracture plane of the HF experiment. We further classify a subset of events based on waveform similarity by calculating network-based cross-correlations coefficients. The clustering based on these coefficients reveals diffuse event clusters within most stages. Events in low pressure regimes at the end of multiple stages form an isolated cluster. The resulting clusters contain highly correlated and highly anti-correlated events. The latter implies the occurrence of opposite mechanisms at similar locations.
Biogeochemical characteristics of Lakes in Western Papua, Indonesia

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Like in most other tropical regions, not much is known about the limnology and (bio-)geochemical state of lakes in Indonesia, especially in the eastern part of the country. Here, for the first time in this region, we investigated biogeochemical processes and nitrogen biogeochemistry in the water column and surficial sediment of two different lakes in western Papua. We put our focus on links between catchment composition on the one side and biogeochemical processes in the water column and within the sediments, as well as the fate of ammonium that is liberated within the sediments, on the other. Two pilot campaigns were conducted in April and November 2017 to measure water column parameters (pH, Dissolved Oxygen, Temperature, anions and cations) and to take short (max 80 cm long) sediment cores at several locations in the two lakes. Lake Sentani consists of four separate basins with maximum water depths of 30 to 40 m, separated by shallow sills. The lake has a geologically very diverse catchment, comprised of many different lithologies. Although all four basins share almost identical surface water chemistry and exhibit sub- to anoxic bottom waters, each basin displays its distinct water column stratification regime and sediment geochemistry. This lake thus harbors a great potential as a natural laboratory for conducting biogeochemical process studies under different environmental/geochemical conditions. Lake Ayamaru is located on a densely forested karstified carbonate platform. The lake level has dropped significantly in recent years due to water loss into the karst, further reduction of open water surface is caused by massive growth of Pistia, a floating plant. Currently the lake has a maximum depth of around 3 m. Its sediment is mainly composed of carbonate minerals, and is methane saturated. In this first baseline survey for both lakes, we carried out detailed analyses of the sediment and its pore water, including analysis of dissolved anions and cations, XRF and XRD analyses of the solid phase, as well as δ15N of pore water ammonium. The data show that the water column and sediment chemistry are strongly controlled by the catchment, which in turn is controlled by climate, morphology and land use. Moreover, they suggest a complex benthic N-cycle, where the (anaerobic) oxidation of ammonium within the sediment pore water does not seem to follow canonical/expected N isotope fractionation patterns.
Can geochemistry in the Critical Zone disentangle climate- from vegetation-driven imprints?

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3.3 - Earth Surface Geochemistry

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The degree of chemical rock weathering is, amongst other factors, controlled by the rock’s initial mineralogy, water flow, temperature, and the weathering reagents it is exposed to. Of these, precipitation and temperature set the above-ground plant community that in turn control the mycorrhizal network as well as the input of Corg and carbonic acid into the weathering zone. While increasing water availability and temperature enhance mineral dissolution kinetics, it is well-documented that biota (and associated reagents) can both increase and slow down weathering reactions or alter the depth at which rock is weathered. The Chilean Coastal Cordillera facilitates to test these abiotic and biotic controls on weathering as it features a steep climate and vegetation gradient, ranging from arid, nearly unvegetated areas in the north to humid, forested areas in the south. With the focus on granitoid rock weathering, we characterized the Critical Zone with depth profile characterization and standard geochemical weathering zone methods at four study sites located in desert (∼26°S), semi-desert (∼30°S), Mediterranean (∼33°S), and temperate (∼38°S) climate zones along the Chilean Coastal Cordillera. Results indicate that 1) denudation rates (derived from in situ produced cosmogenic nuclides) increase from north to south and range from 10 t km⁻² yr⁻¹ to 50 t km⁻² yr⁻¹; 2) the degree of chemical weathering (quantified by the chemical depletion fraction, CDF) in the four sites is moderate to low, with differences only being significant between the arid and sparsely vegetated site and the three other sites; 3) strong vertical gradients in CDF are absent, such that these gradients are at depths greater than 2 m; 4) the thickness of the A and B horizons and the degree of elemental depletion and enrichment in these horizons increase from north to south; 4) within one study site, soils on high-insolation slopes (N-facing) are thinner than on their low-insolation analogue (S-facing) but do not show any difference in CDF; and 5) regardless of these regional variations in weathering intensity and soil thicknesses, weathering is kinetically limited in all four sites. Even though clear indicators of weathering characteristics that allow to distinguish the abiotic (solely climate-related) from biogenic driver have not yet emerged, we could show that the availability of mineral-derived nutrients decreases with increasing vegetation density along the precipitation gradient form north to south. Further we could demonstrate that the enrichment of P (and partly Mg) in the A horizon compared to the B horizon in the two southernmost, most vegetated sites, is attributed to nutrient uplift and recycling by plants.
Injection of fluids (e.g. brines, CO2, steam) into the reservoir is common practice in oil production in order to push the crude oil in place towards production wells and thereby enhance oil recovery (EOR). To optimize these procedures, it is essential to know the spatial propagation of injected fluids in the subsurface. Oil and injected fluid typically differ in their electrical resistivity, which can be detected with electromagnetic methods, e.g. by monitoring the distribution of (resistive) oil and (conductive) fluids. Here, we present an overview of soft- and hardware developments, modelling results and time-lapse field data obtained over five years in the framework of a monitoring project of an onshore oilfield in NW Germany. CSEM modelling studies focusing on identification of suitable source-receiver configurations showed that despite sizable resistivity contrasts (1-2 orders of magnitude) conventional surface-based measurements do not provide sufficient resolution to thin (<15 m) reservoirs located at ~1200 m depth. However, the study showed that sources and/or receivers with vertical components increase sensitivity to such reservoirs very significantly. Furthermore, highest discrimination power of all EM field components is provided by the vertical electric field. Based on the modelling results, a novel horizontal-vertical dipole source using the steel casing of a 1.3 km deep abandoned oil-well was successfully deployed and used for current injection in three time-lapse CSEM surveys (2014-2016) across the oilfield. In addition, we developed a novel numerical framework to compute the effect of metal casings on CSEM data and included it into our existing modelling and inversion (imaging) software. Induction effects in steel casings of oil wells increase EM energy at greater depths, e.g. towards the reservoir. We also developed a receiver chain to measure the vertical electric field in a shallow observation borehole. Repeatability of the measured data – an essential prerequisite for any monitoring application – has been proven excellent between the surveys. This is remarkable because sources and receivers had to be removed and reinstalled between surveys and because an active oil field produces high amounts of EM noise (pipelines, power lines, train tracks, windmills etc.). Currently, we are working on a new numerical framework for 4D CSEM inversion in order to image changes of the 3D electrical conductivity structure inside a reservoir between surveys directly. A cascaded inversion scheme in combination with a-priori information (conductivity constraints) and weighting of subdomains of the modelling space shows promising results in solving this mathematically ill-posed problem.
Interfacial reactivity between green rust sulfate (GRSO4) and arsenic

Jeffrey Paulo Perez

4.4 - Interface Geochemistry

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Elevated levels of arsenic (As) in groundwaters remain a significant public health and environmental concern because of its toxicity. The fate and mobility of As is influenced by its interaction with dominant (redox-active) mineral phases in groundwaters. Among these phases, ‘green rust’ (GR), which belongs to a family of Fe(II)-Fe(III) layered double hydroxides, plays a crucial role. However, the critical parameters of As uptake by GR minerals are not yet fully understood. To elucidate the interfacial reactions between GR sulfate (GRSO4) and As species, we carried out batch adsorption experiments by varying environmental parameters such as pH, adsorbent loading, ionic strength, contact time and initial As concentrations. At relevant contaminated groundwater concentrations (10 mg L-1), our results showed that GRSO4 is a stable and effective mineral substrate for the sequestration of As in water. The removal of As(III) was found to be significantly higher in alkaline environments (∼95 %) while As(V) was more efficiently removed at near-neutral conditions (>99%). The measured maximum adsorption capacities of As(III) and As(V) on GRSO4 are 160 mg g-1 (pH 8-9) and 105 mg g-1 (pH 7), respectively. Our results also revealed that groundwater chemistry also influences the efficiency of As removal, especially at high ionic strengths and in the presence of common groundwater ions such as Mg2+ and PO43-. Overall, our study, therefore, clearly highlights the influence and importance of redox-active GR mineral phases in uptake and release of As in contaminated groundwaters.
Towards an enhanced moment tensor catalog of the Alps

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2.1 - Physics of Earthquakes and Volcanoes

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With its dense seismological network of more than 700 broadband stations, the European AlpArray initiative provides the possibility to obtain better insights on regional seismicity patterns as well as on source processes of single earthquakes. Within the scope of our AlpArray subproject “From Top to Bottom – Seismicity, Motion Patterns & Stress Distribution in the Alpine Crust” we aim to investigate the geodynamic processes which control the multi-scale seismicity of the Alps. The seismicity of the Alps appears to be diffuse, and is mostly characterized by weak to moderate magnitudes, rarely resulting in damaging earthquakes (e.g. the 1976 Mw 6.5 Friuli earthquake, with almost 1000 casualties). Understanding the Alpine seismicity and the geometry and extent of active faults can benefit from seismic source studies, and in particular from moment tensor inversion. Moment tensor catalogs, as provided for example by Geofon, gCMT and INGV, are mostly limited to magnitudes above Ml 4. The dense deployment of the AlpArray seismic network can be used to extend the target of regional moment tensor inversions to weaker earthquakes. A future enhanced moment tensor catalog for the Alpine region will provide important new information to study seismic source processes and stress distribution in the Alps. In this work, we present a recollection of available moment tensor solutions for the area and discuss challenges, opportunities and possible implementations for a moment tensor inversion at local to regional distances. We will show some preliminary moment tensor inversion results for weak earthquakes with magnitudes between Ml 3.2 and Ml 4.
Sources of reduced sulphur for the George Fisher Zn-Pb-Ag shale-hosted massive sulphide deposit – sulphur isotope ($\delta^{34}S$) microanalysis (SIMS) of pyrite

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3.1 - Inorganic and Isotope Geochemistry

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The Proterozoic Mount Isa Inlier is an exceptional metallogenic province and is host to several world-class base metal deposits. Most important are the shale-hosted Mt. Isa Cu, Mt. Isa Zn-Pb-Ag and George Fisher Zn-Pb-Ag deposits. These deposits are hosted by the carbonaceous, pyritic, Paleo-proterozoic (ca. 1645-1660 Ma) Urquhart Shale of the Mt. Isa Group. The Urquhart Shale contains several 100 Mt of sulphides. Having undergone multiple stages of deformation, the Urquhart Shale and associated base metal deposits contain multiple generations of fine-grained sulphides, and the source(s) of reduced sulphur remain unclear. In this study we present $\delta^{34}S$ values for pyrite ($\delta^{34}Sp$ryrite) associated with the George Fisher Zn-Pb-Ag deposit. The $\delta^{34}S$ values were determined in situ, using Secondary Ion Mass Spectrometry (SIMS), ensuring spatially resolved (< 5 µm) isotopic data were produced for all generations of pyrite. The paragenetically constrained $\delta^{34}Sp$ryrite values provide valuable information about the processes responsible for sulphide generation in and around the George Fisher deposit. The paragenetic relationship between pyrite and base metal sulphides was determined using reflected light petrography and backscatter electron imaging. Multiple generations of pyrite were identified: 1) fine-grained (≤ 10 µm) subhedral-subspheroidal pre-ore pyrite; 2) coarse-grained (100-600 µm) anhedral pyrite associated with Stage 1 sphalerite mineralisation; 3) coarse-grained (100-400 µm) euhedral pyrite associated with Stage 2 galena and sphalerite mineralisation; and 4) coarse-grained (100-400 µm) euhedral pyrite within un-mineralised rocks. The $\delta^{34}S$ values for all pyrites are distributed between -6 ‰ and +34 ‰ ($n = 356$). Whereas pre-ore pyrite (Py-1) preserves negative $\delta^{34}S$ values (-6 ‰ to +3 ‰), the ore stage pyrites (Py-2 and Py-3) preserve higher $\delta^{34}S$ values (+2 ‰ to +18 ‰). The highest $\delta^{34}S$ values are preserved in the coarse-grained pyrite from un-mineralised rocks (Py-4: +16 ‰ to +34 ‰). The negative $\delta^{34}S$ values (Py-1) provide evidence of bacterial sulphate reduction (BSR) of seawater sulphate under relatively open system conditions. In contrast, the ore-stage pyrites (Py-2 and 3) could have formed during more closed system BSR, but it is not possible to rule out other pathways of sulphate reduction (e.g. thermochemical sulphate reduction; TSR). Pyrite 4 preserves the most positive $\delta^{34}S$ values, which may provide evidence of more extreme sulphate limitation. The overall distribution of $\delta^{34}S$ values in pyrite from the Urquhart Shale and George Fisher deposit are similar to other sediment hosted base metal sulphide deposits formed during the Paleo-proterozoic. Despite undergoing multiple stages of deformation, the similarity in $\delta^{34}Sp$ryrite values at the George Fisher deposit provides evidence that common processes were ultimately responsible for sulphate reduction.
Flood Vulnerability in private sector

Nivedita Sairam
5.4 - Hydrology

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This research focuses on changes in flood damage and losses for the private sector, i.e. households due to changes in vulnerability. Damage and loss may refer to building or building content. The basic skeleton for loss estimation has three parts – Hazard, Exposure and Vulnerability. The natural sciences oriented concept defines vulnerability as the degree of loss to a given element at risk resulting from the occurrence of a natural phenomenon (hazard), e.g. a flood, of a given magnitude. Private precaution is an important component of vulnerability. However, quantitative knowledge about vulnerability reduction via private precaution is scarce and their effects are hardly considered in loss modelling and risk assessments. To quantify the average effectiveness of private precaution in reducing flood loss to residential buildings, empirical vulnerability data of households with and without precautionary measures are classified into treatment and control groups and matched. This provides us with two distinct groups of households differing only in vulnerability due to private precaution. Results from the analysis of these data yields an estimated average effect of implementing private precaution of EUR 13000 per household, and thus confirm the significant effectiveness of private precautionary measures in mitigating flood loss. The future work includes an implementation of Hierarchical Bayesian Networks for vulnerability analyses and modelling of changes in vulnerability. The model will be validated for spatial transferability (international) using empirical and synthetic flood loss datasets from the UK. An advantage is that, these algorithms may be able to identify even subtle relationships between the parameters. Challenges with the dataset include missing data points and uncertainty/noise in the data. I expect that, overcoming these challenges and implementing defined methodologies will include several new designs that might also be a novelty in the overall research work.
Long-term high-performance co-digestion of sewage sludge and rapeseed oil

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5.3 - Geomicrobiology

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Anaerobic digestion for the production of biogas is a promising renewable energy source. Unfortunately, biogas plants are often operated below their technical production maximum due to their susceptibility to process failures at high organic loading rates (OLR) or changing process conditions. In former studies at the GFZ, a procedure for stabilizing biogas processes co-digesting lipid-rich and thus energy-rich substrates at high OLR was developed. Therefore, CaO is added to the process in case of an imminent process failure indicated by the early warning indicator (EWI) EWI-VFA/Ca. The addition of CaO led to an increase in the pH and to the formation of process stabilizing aggregates that adsorbed toxic long chain fatty acids (LCFAs) and provided surfaces for biofilm formation. Four lab-scale experiments were conducted in order to test the applicability of this method for long-term high-performance co-digestion (t ≥ 100 d; OLR > 4 kg VS m⁻³ d⁻¹). Sewage sludge and rapeseed oil were used as substrates. The OLR was increased in two experiments slowly (every two weeks by 0.9 to a max. of 6 kg VS m⁻³ d⁻¹) and in two experiments fast (every two weeks by 1.4 to a max. of 9 kg VS m⁻³ d⁻¹). During the OLR increase and the high performance operation several warnings of process failures were shown by the EWI-VFA/Ca, accompanied by decreases in the biogas yield. CaO additions stabilized the processes efficiently indicated by increases in the biogas yield and decreases in the EWI value. In all experiments the high-performance operation was kept stable over more than 100 days. Therefore, the long-term high-performance co-digestion of lipid-rich substrates is possible if the EWI-VFA/Ca is used for process monitoring and if necessary, CaO as a countermeasure. In the course of the CaO additions the formation of small aggregates (1 – 5 mm) was observed that consisted mainly of calcium and lipids that were embedded in a protein matrix, indicating the presence of biofilms. They presumably had a stabilizing effect on the systems due to the storage of LCFAs and the biofilms, where microorganisms are protected against toxic conditions. With increasing oil loadings the relative abundance of syntrophic, fatty acid oxidizing bacteria of the genus Syntrophomonas and Syntrophobacter increased, showing that the bacterial biocenosis adapted to the lipid-rich substrate. Due to the high concentration of LCFAs that can only be degraded via syntrophic beta-oxidation, hydrogen consuming hydrogenotrophic Methanospirillum sp. dominated the archaeal community within the aggregates, whereas in the sludge acetoclastic Methanosaeta sp. dominated the biocenosis of methanogenic archaea.
Influence of mineralogy and microstructures on strain localization and fault zone architecture of the Alpine Fault, New Zealand

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4.2 - Geomechanics and Rheology

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The Alpine Fault on New Zealand’s South Island is an oblique, dextral strike-slip fault that accommodates the majority of displacement between the Pacific and the Australian Plates and presents the biggest seismic hazard in the region. Along its central segment, the hanging wall comprises greenschist and amphibolite facies Alpine Schists. Exhumation from 35 km depth, along a SE-dipping detachment, led to mylonitization which was subsequently overprinted by brittle deformation and finally resulted in the fault’s 1 km wide damage zone. The geomechanical behavior of a fault is affected by the internal structure of its fault zone. Consequently, studying processes controlling fault zone architecture allows the assessment of the seismic hazard of a fault. Here we present the results of a combined microstructural (SEM) and mineralogical (XRD) investigation to evaluate the influence of mineralogical composition, alteration and pre-existing fabric on strain localization and to identify the controls on the fault zone architecture, particularly the locus of brittle deformation in P, T and t space. Samples originate from several locations along the Alpine Fault and the Deep Fault Drilling Project phase 1A (DFDP-1A). Logging data from phase 2 (DFDP-2) provide further constraints. Field observations reveal that the fault’s principal slip zone (PSZ) is either a thin (<1 cm to <7 cm) layered structure or a relatively thick (10s cm) package lacking a detectable macroscopic fabric. Lithological and related rheological contrasts are widely assumed to govern strain localization. However, our preliminary results suggest that qualitative mineralogical composition has only minor impact on fault zone architecture. Quantities of individual mineral phases differ markedly between fault damage zone and fault core at specific sites, but the quantitative composition of identical structural units such as the fault core, is similar in all samples. This indicates that the degree of strain localization at the Alpine Fault might be controlled by small initial heterogeneities in texture and fabric or a combination of these, rather than by variations in mineralogy. Further microstructural investigations are needed to test this hypothesis.
Monitoring soil moisture using cost efficient GNSS receivers at station Marquardt, Germany

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1.1 - Space Geodetic Techniques

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With the development of the Global Navigation Satellite Systems (GNSS) new techniques for water estimations in the atmosphere and in soils have been established with several key advantages. Standard geodetic GNSS ground-based stations can provide the possibility for estimating Volumetric Water Content (VWC) in soils. Cheap single-frequency GNSS receivers might provide similar performance for a reduced price, thus widening the range of water cycle products that can continuously be monitored with GNSS.
Modelling the formation and development of caverns in rock salt

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In Germany, salt deposits play an important role as industrial raw material as well as for energy storage. However, in case of a geological interference zone rock salt comes into contact with groundwater which may lead to the formation of geogenic caverns representing high risk to active potash and rock salt mining. In such cases, fluids migrate through fissures into the salt and start dissolving it subsequently leading to decompaction of the rock mass which may end up in subsidence of overlying structures. Therefore, damages at the surface as well as for the mine structures may result. The main aim of the project “ProSalz” is to improve the process understanding of reactive multi-phase flow in the transition zone between caverns and solid rock in order to facilitate a safe long-term retention of caverns within rock salt. The Fluid Systems Modelling Section is responsible for the numerical simulations as well as the data management of the project. The aim of my doctoral thesis is to create several models on different spatial scales and to perform sensitivity analyzes within the parameter space of geochemistry and hydromechanics in order to support the conceptualization of laboratory and field experiments. Using data from laboratory measurements will finally help me to create more complex models and to calibrate them, so the chemical as well as the hydromechanical behavior of the caverns can be modeled and the mechanical stability can be evaluated. So far, base models of all laboratory and field experiments have been created and different scenarios tested. The results provide important information about geometry, pressure and chemical composition of fluids to help design the experiments. While the dissolution process of salt is very fast, some transport mechanisms were shown to be too slow and therefore not relevant within the time frame of the project. Furthermore, the dissolution process along geological faults (cracks or fissures) in rock salt has been modelled in order to verify an existing approach that describes the development of natural caverns. The results significantly depend on the NaCl-concentration and the fluid velocity. All in all, the models quantify the geochemistry very well but not the hydromechanics yet. So far the geometry is highly simplified. Therefore, the next step is to improve the base models by using Navier-Stokes equations instead of Darcy’s Law and to model natural cavern systems of higher complexity. Available measurement data will be compared to the results in order to calibrate them. The final step after geochemistry and hydromechanics are implemented is to model the mechanical behavior of rock salt in order to evaluate the long-term stability of natural and technical caverns.
The use of ADCP to estimate suspended sediment concentration in Mekong River Delta

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Studying the suspended solids concentration (SSC) is fundamental for understanding sediment dynamics in both rivers and estuaries. However, SSC is strongly influenced by different processes and factors like tidal flows and salt water dynamics, water depth, current and wind. This makes the measurement of SSC rather difficult. Water samples for laboratory analysis provides reliable values of SSC and grain size, but due to the typically low temporal and spatial sampling frequency continuous time series or accurate estimations of SSC for large rivers are hardly obtained. Optical backscatter sensors and transmissometers provide alternatives for continuous point measurements. However, they need to be calibrated, which is difficult because of the nonlinear relation between measured turbidity, SSC and grain size distribution. Moreover, the optical sensors require frequent maintenance to avoid biological fouling. Recently, acoustic Doppler current profilers (ADCP) for measuring water discharge are used for determining SSC at the same time. By analyzing the acoustic backscatter, ADCP can also provide a wealth of data to compute suspended sediment concentration with high resolution both in time and space. In addition, the sediment flux can be easily estimated, because ADCP provide data of river velocity and SSC at the same time. To further evaluate the application of this technique using commercially available instruments, profiles of suspended sediment concentrations are estimated from acoustic backscatter intensity recorded by RD Workhorse ADCP 614 kHz in the Mekong River Delta. The main scientific objectives of the study is develop an empirical equation for hydroacoustic detection of suspended sediment in rivers and estuaries, then extend the results to present consistent estimates of the sediment flux in the entire delta derived from operational ADCP discharge measurements.
Quantitative soil organic carbon predictions based on reflectance spectroscopy and a spectrally clustered European-wide soil spectral library

Kathrin Ward

Soil organic carbon (SOC) is an important soil property with regard to soil degradation and many ecosystem services that soils are providing such as food production and carbon sequestration in the context of climate change. As an alternative to wet chemistry, the estimation of SOC can be conducted by reflectance spectroscopy which is an inexpensive, rapid and accepted technique that has been used widely especially in the laboratory. A disadvantage of such approaches is the need for a sufficient number of spectrally similar calibration and validation samples. In our study we aim to reduce the need for validation samples by calibrating robust SOC prediction models based on a large scale soil spectral database. We used the European-wide LUCAS database consisting of spectral measurements and SOC contents. Generally, on large scales the accuracy of spectral models decreases due to non-linear relationships between spectral reflectance and SOC content. Therefore, we investigated if spectral clustering can improve the model performance compared to reference models which were calibrated on the whole database using PLS and random forest regression. We tested a k-means clustering combined with PLSR models and a LOCAL PLSR approach. In the LOCAL approach for each validation sample a separate model was calibrated based on a subset of the most similar samples selected out of a calibration sample pool. These models were then used to predict the SOC content for the particular validation sample. Additionally, we intend to make a step towards adapting this method to air- and spaceborne hyperspectral data such as EnMAP. These hold a great potential to map SOC on larger scales and perform regular updates without the need for local ground databases. Therefore, we adapted our modelling process by removing the water vapour spectral bands which are the wavelengths that are not available from remote sensing data. Moreover, our approach is solely based on the spectral information, and thus, applicable to image data without the need for additional lab measurements, while the SOC content is only used for validation. Overall the best results were achieved by the LOCAL approach compared to the best reference model which was based on random forest regression. The k-means approach did not substantially improve the results of the reference models. Our results are comparable to those of other studies on large scale databases. This study shows that it is possible to improve the prediction accuracy of SOC by portioning the database into smaller groups. But it also shows that overlapping, individual groups are preferred over fixed ones.
Quantifying rock weakening due to decreasing calcite mineral content by numerical simulations

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Predicting changes in rocks mechanical properties due to chemical reactions is of particular importance, since mineral dissolution and precipitation may significantly affect effective mechanical rock behaviour. Changes in elastic properties are of paramount relevance for risk assessment within the context of geological subsurface utilization, regarding reservoir, caprock and fault integrity. The main factors contributing to macro-scale elastic rock properties are microstructure and mineral volume fractions as well as the constituents’ moduli. In addition to the experimental determination of elastic rock parameters, a variety of analytical methods for their calculation exists. However, none of the analytical models can determine elastic rock parameters for multi-component systems over a broad range of volume fractions and complex rock microstructures. In the present study, effective elastic moduli of two digital rock samples, the Fontainebleau and Bentheim sandstones, are numerically determined based on micro-CT images. Reduction in rock stiffness due to the dissolution of 10 % calcite cement by volume out of the pore network is quantified for three synthetic spatial calcite distributions (coating, partial filling and random distribution), using representative sub-cubes derived from the digital samples. Moreover, the impact of different initial elastic moduli of the calcite cement is considered. Bulk and shear moduli decrease by 34 % and 38 % in maximum due to the reduced calcite content, respectively. Total porosity is clearly the dominant parameter, since spatial calcite distribution has a minor impact on the results, only, except for a randomly chosen calcite distribution within the pore network. Here, the calcite cement is interconnected and stabilizes the rock matrix. Further, applying a 47 % softer initial stiffness for the calcite cement results only in a slightly weaker mechanical behaviour. Using the introduced quantitative approach improves the accuracy of predictions on chemically-induced changes in elastic rock properties, compared to general analytical methods. It allows for quantification of rock property changes due to variations in mineral composition and microstructure, and further enables quantification of uncertainties related to the spatial distribution of porosity and mineral components as well as the applied initial cement moduli.
Exploring upper tail estimators to assess the heavy-tail behavior of extreme precipitation in Germany

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Extreme value distributions of hydro-meteorological variables often exhibit heavy-tail behavior. Since hydro-meteorological extremes are of high relevance to society and ecosystems, a reliable identification of upper tail behavior is of great importance. Several methods are applied to identify and quantify the upper tail behavior of distributions, including graphical and numerical methods. Numerical methods (e.g. Shape parameter of GEV, L-skewness, L-kurtosis, Upper tail ratio, Obesity index) are objective and more suitable for large data sets, however, the choice of appropriate numeric estimators remains challenging. Our aim in this study is therefore to compare different numerical methods in order to identify robust upper tail estimators for the analysis of large data sets. We focus on a long-term and gap-free data set of daily precipitation from 1200 German weather stations and test different approaches of calculating the set of numerical estimators. Even though all upper tail estimators focus on the same sample of extremes, their application leads to significant differences in their estimation of upper tail behavior. Moreover, seasonal differences are found between upper tail estimators. We recommend to use a set of upper tail estimators to obtain an overall better impression of the tail behavior of hydro-meteorological extremes.
Determining frequencies and directions of radio transmitters for robust processing of radio magnetotelluric data

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2.7 - Near-Surface Geophysics

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Contrary to the magnetotelluric method (MT) with its natural electromagnetic sources, the high-frequency pendant - radio magnetotelluric method (RMT) - relies on exciting signals from radio and military transmitters within the frequency bands VLF (3-30 kHz), LF (30 - 300 kHz) and MF (300 - 3000 kHz). Similar to MT, RMT images the electric conductivity distribution with depth; a parameter which is sensitive to e.g. fluids, clay and mineralizations. Due to the higher frequency EM variations, RMT has a typical depth of investigation of $\sim$100 m and is applied for near surface investigations.

From the electric and magnetic field variations measured at the Earth’s surface and transformed into frequency domain, the (R)MT impedance tensor is computed that carries the electrical conductivity information of the subsurface. To make use of established MT time series processing tools for RMT processing, several modifications are required. These transmitters provide reasonable and strong signals at distinct transmitting frequencies in contrast to MT with an excitation resembling white noise, i.e. random signal having more or less equal intensity at different frequencies. Therefore RMT processing requires the picking of all discrete frequencies with higher power density which originate from single radio transmitters within the spectral range of interest. In addition, the signal must be reasonably stable and coherent for a successful computation of the RMT impedance tensor. This is ensured by calculating univariate coherences between the output channels (Ex, Ey) and input channels (Bx, By). To integrate the RMT-specific workflow into the existing EMERALD processing software (Ritter et al., 1998; Weckmann et al., 2005) an interactive C++ program has been developed. Its graphical user interface allows to evaluate and select usable radio transmitter frequencies. It also determines the transmitter directions from the recorded horizontal components of the magnetic fields. Different incident direction of the EM fields are finally required to compute the RMT impedance tensor. We will introduce the new interactive program and show first results of RMT time series processing.
Geochemical and microbial co-succession in a High-Arctic proglacial area

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Recently deglaciated environments are ideal for studying the initial development of soils through the co-6 succession of freshly exposed rock weathering and microbial ecosystems. Carbon (C), nitrogen (N) contents as well as soil pH and soil geochemical elemental composition are thought to be dominant factors structuring the 8 bacterial, archaeal and fungal communities in the early stages of soil development. However, the functional 9 linkages between C and N contents, soil geochemical elemental composition and microbial community 10 structures remain poorly understood. Here, we examined the variations in geochemical properties and associated 11 microbial structures along a transect in the proglacial area of a High-Arctic glacier (Longyearbreen, Svalbard). 12 Our results reveal that C and N contents and isotopic compositions as well as weathering advancement and 13 microbial abundance and community structure change in tandem along the transect. We found significant 14 relationships between microbial community structures and total organic carbon (TOC), total nitrogen (TN) as well as Ca, Mg and Si. We suggest that the observed microbial and geochemical co-succession patterns along the 16 transect are primarily the result of the geomorphological heterogeneity of the proglacial terrain.
Mineral nanoparticles in hydrothermal magnetite: A critical indicator of a local kinetic effect

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4.3 - Chemistry and Physics of Earth Materials

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Mineral replacement experiments at laboratory timescales suggest a crucial role of the interfacial boundary layer at fluid-mineral interfaces. However, it is still unknown whether this local kinetic effect will survive geological timescales because the primary information could be rapidly superimposed by re-equilibrated processes. Here we report that in a fluid-driven skarn system, zinc spinel nanoparticles precipitated at local fluid-mineral interfaces are preserved in magnetite, despite the fact that Zn concentrations may be less than 100 ppm in the initial bulk fluid. Based on a steep increase of Ca and Sr contents from magnetite core to rim, we propose that a transient involvement of carbonate-rich fluid has provided a corresponding increase of pH value and presumable Zn$^{2+}$ and Mg$^{2+}$ ions in small amounts. More importantly, the layered distribution of exsolved nanometer Al-Si lamellae suggests that the Al concentrations could be rapidly enriched in the interfacial boundary layer. Finally, the increased reacting ions and pH value at fluid-magnetite interfaces have reached supersaturation of zinc spinel phase, and subsequently used the magnetite crystal lattice as a template for nucleation and growth. It will soon be overgrown by the ongoing growth of magnetite and the related moving interface. However, a strong competition for Zn$^{2+}$ and Mg$^{2+}$ by magnetite crystallization from surrounded fluid would suppress a continuous growth of zinc spinel after its nucleation, which is consistent with a decreased size whilst an increase in number along the magnetite growth direction. This study not only explains abnormal enrichment of incompatible elements in magnetite, but also provides a new perspective for the redistribution of elements at fluid-mineral interfaces.
Organic sulfur compounds (OSCs) represent one of the main forms of sulfur in sedimentary rocks. The abundance and distribution of OSCs are influenced by depositional environment and thermal maturity. Different analytical methods have been applied for characterization of OSCs e.g., GC-MS, Py-GC-MS and XANES. Fourier transform ion cyclotron resonance mass spectrometry (FT-ICR-MS) is a cutting edge technique and it has been successfully used for characterization of OSCs in fossil fuels combined with different ionization techniques, such as atmospheric pressure photo ionization (APPI) and electrospray ionization (ESI) (e.g., Purcell et al., 2007; Shi et al., 2010). The ultra-high mass resolving power, resolution and mass accuracy of FT-ICR-MS make it possible to assign elemental compositions to each peak in the mass spectrum and it has incomparable advantages in characterization of heteroatomic and high-molecular-weight compounds. Generally, sulfur containing elemental formulas can be grouped into elemental classes and compound classes, and additionally characterized by DBEs (number of double bond equivalent), which provides a brand new aspect to characterize OSCs. Solvent extracts (30:38:32 methanol: acetone: chloroform) of three sets of source rock samples from Niobrara, Barnett and Wealden Formation, with varying lithofacies, depositional environment, kerogen types and thermal maturities were analyzed to identify the possible variations of OSC geochemistry. In addition, two samples from reservoir units of Barnett and Niobrara Formation were also added to investigate possible migration effects. Overall, OSCs in Wealden samples are significantly different with those in Niobrara and Barnett samples in both positive APPI and ESI(-) measurements. OSCs in Wealden sample extracts are dominated by OxSz compound classes. This is different from Niobrara and Barnett samples where NySz and Sz compound classes are dominating OSCs in APPI(+) and ESI(-) measurements, respectively. Besides, OSCs in Wealden samples are characterized by low DBEs (<15), while DBE of OSCs in Niobrara and Barnett samples can reach 30. For carbon number distribution of compound classes S1 and S1O1, Barnett and Niobrara samples are dominated by C30, but for Wealden samples, there is an extra C40 local maximum, which may be related to relative enrichment of diagenetic and catagenetic products of sulfur-linked β-carotane. The free β-carotene has also been identified in the saturated hydrocarbon fraction of Wealden extracts (Rippen et al., 2013). The speciality of characterization of OSCs in Wealden samples is mainly attributed to the depositional environment and thermal maturity. Higher abundance of OSCs can always be detected in Niobrara samples than in Barnett samples under different ionization conditions. In addition, even though DBE distributions of OSCs in Niobrara and Barnett samples have similar local maxima and ranges, but local maxima with higher DBEs contribute more to Barnett samples, which indicates higher aromaticity of OSCs in Barnett samples. Detailed comparison of carbon number (CN) distribution of S1 compound classes under positive APPI mode shows that Barnett samples always have narrower CN ranges of S1 compound classes than Niobrara samples. The differences cannot be only attributed to lithofacies variations, thermal maturities could also lead to diversity of OSCs. Besides, comparison between OSCs in Barenett and Niobrara source rocks and reservoir rocks under positive APPI mode indicate the relative enrichment of OxSz and loss of NySz and Sz elemental classes during migration.

Studies of the seismic discontinuities in the mantle transition zone (MTZ), which are at depths of about 410 km and 670 km, with converted seismic waves have been used to infer temperature and composition of the MTZ. However, as there are diffractional effects of P waves as well as teleseismic receiver functions, the traditional ray theory, actually a high-frequency approximation, may lead to some limitations such as that when the length scale of anomalous topography is comparable to the wavelength of the seismic waves. So we propose a new inverse relationship considering the finite frequency effect. We calculate 2-D boundary sensitivity kernels of the traveltime and then use the synthetic seismograms based on SEM to make a comparison between the results of our method and that of ray theory. It shows that traditional ray theory overpredicts traveltime anomalies when the topography length scale is about 400 km and the finite frequency method is able to properly predict traveltime observations.
Empirical modeling of the plasmasphere dynamics using neural networks

Irina Zhelavskaya
2.8 - Magnetospheric Physics

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We present a new empirical model for reconstructing the global dynamics of the cold plasma density distribution based only on solar wind data and geomagnetic indices. Utilizing the density database obtained using the NURD (Neural-network-based Upper hybrid Resonance Determination) algorithm for the period of October 1, 2012 - July 1, 2016, in conjunction with solar wind data and geomagnetic indices, we develop a neural network model that is capable of globally reconstructing the dynamics of the cold plasma density distribution for $2 \leq L \leq 6$ and all local times. We validate and test the model by measuring its performance on independent datasets withheld from the training set and by comparing the model predicted global evolution with global images of He$^+$ distribution in the Earth’s plasmasphere from the IMAGE Extreme UltraViolet (EUV) instrument. We identify the parameters that best quantify the plasmasphere dynamics by training and comparing multiple neural networks with different combinations of input parameters (geomagnetic indices, solar wind data, and different durations of their time history). We demonstrate results of both local and global plasma density reconstruction. This study illustrates how global dynamics can be reconstructed from local in-situ observations by using machine learning techniques.
Time series of a volcano crater morphology: Insights from aerial photogrammetry at Volcán de Colima, Mexico

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Volcanic craters may rapidly change their morphology, excavate during explosions and refill by extrusions of lavas. Because of the difficult and hazardous access, data revealing these morphometric changes are limited and understanding the development of the summit craters is often unclear. The use of airborne images in photogrammetry is one of the best and most precise tools for reconstructing local morphology and features at volcanic craters or lava domes and recent advances in UAVs provide a cheap and easy solution for image acquisition from a safe distance. Here, we utilize images acquired by UAVs as well as by helicopter and plane, also comparing the photogrammetric data to radar observations from the high resolution TerraSAR-X satellite. We present a time-series of very high resolution digital elevation models at the Colima crater spanning ~3 years, providing insight into morphologic changes, local eruptive processes and crater evolution. Our results at Volcán de Colima reveal the rapid morphometric changes during extrusion and explosion stages and allow the identification of oblique growth and directions of coulees and lava flows. This displays a highly dynamic crater system, showing repeated dome growth and explosive destruction episodes with an inferred inclined vent geometry and repeated crater breaching. We could identify distinct explosion vents and fracture sets within the dome as well as degassing pathways. Our methods and results are similarly applicable at other steep sided volcanoes, where direct access is difficult or hazardous.
EGU posters

Poster Session 1: 11:15 – 12:15
(odd Poster No.)

Poster Session 2: 13:45 – 14:45
(even Poster No.)

Poster No. is NOT the page Number!
Testing the Effects of Different Magnetopause and Chorus-Wave Models, and Low Energy Seed Population on the Dynamics of the Outer Radiation Belt

Angelica Castillo

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Outward radial diffusion combined with magnetopause shadowing are often responsible for fast dropouts of radiation belt electron fluxes. Depletions at higher L-shells due to magnetopause compression are observed for a large range of energies and can be thereby separated from EMIC-wave produced pitch-angle scatter. Studies using low energy electron seed populations have accurately reproduced enhancement of storm-time electron fluxes, suggesting the importance of these particles. Whistler mode chorus waves, specially on the night sector, lead to local heating of particles and thereby to their acceleration and scattering. Measurements of peaks in electron phase space density in $L^*$ regions inside geosynchronous orbit suggest major influence of chorus waves on the dynamics of electrons in the outer radiation belt. A variety of physical parameters that account for the processes named above have been applied to a long-term simulation (Oct-2012 to April-2013) of the radiation belts using the VERB code, with the aim of reproducing fast dropouts of electron fluxes and the wipe out of the outer radiation belt after storm times.
Space weather and data assimilation

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The dynamical evolution of the radiation belts has been a subject of extensive research since the belts' discovery in 1959, and can be described as a balance between acceleration and loss processes. Understanding these mechanisms is crucial to understand and predict the response of the belts to geomagnetic disturbances. This is of great importance to satellite operators, engineers, and designers, as the charged particles can cause spacecraft anomalies and damage satellite hardware. Analysis of radiation belt observations presents a major challenge. Satellite observations are often restricted to a limited range of L-shells, pitch angles, and energies. Additionally, observations at different L-shells are taken at different points along the spacecraft orbit and therefore at different times. As a consequence, to fill the spatiotemporal gaps and to understand the dynamics and dominant physical processes in the radiation belts as well as to create accurate statistical models, observations should be blended with physics based dynamical models. In the 1970s, numerical weather prediction faced similar problems to those mentioned. A methodology that combines observations and models in order to produce results close to the true values was applied. This algorithm minimizes errors by combining observations with a model in an optimal way and is usually referred as data assimilation. Since then, data assimilation methods have been extensively used to analyze and predict meteorological, oceanographic, and climate processes. With the advent of space-borne observational data and the development of more sophisticated space-physics models, dynamical processes in the Earth’s radiation belts can be analyzed and assessed using data assimilation methods. In this study, reanalysis of radiation belt electrons is achieved through data assimilation of Van Allen Probes Mission and Geostationary Operational Environmental Satellite with the 3D Versatile Electron Radiation Belt code using a split-operator Kalman filter technique.
Early ore-forming fluids at the world-class Panasqueira W-Sn-Cu deposit (Portugal). Insights from in-situ laser ablation ICP-MS and SIMS studies.

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3.1 - Inorganic and Isotope Geochemistry

Hydrothermal fluids flowing through the upper crust formed most of the earth’s ore deposits. Thus, developing methods that help to trace the fluid origin and evolution is essential to understand ore formation and to improve exploration strategies. Isotopic and trace-element compositions of minerals and fluid inclusions can be used as fingerprints of these processes and advances in in-situ micro-analytical methods such as SIMS and LA-ICP-MS now allow the detection of geochemical variations at the micron scale. The Panasqueira vein-type W-Sn-Cu deposit is hosted by pelitic-psammitic metasediments of Cambrian age and related to a partially greisenized two-mica S-type granite emplaced during the late stages of the Variscan Orogeny (Kelly and Rye, 1979). White mica is one of the most abundant hydrothermal minerals in the deposit, including the greisen and wall-rock alteration zones, which predate the main ore stages. White mica is also an abundant mineral in the ore veins, from the pre-ore to the main ore stage. In contrast, tourmaline is the main phase forming the wall-rock alteration, but it is scarce in the mineralized veins, forming only locally at the edges of the veins and also in late-stage fractures. We present results of a comprehensive set of in-situ microprobe (major elements), LA-ICP-MS (trace elements) and SIMS (B-isotopes) measurements of coexisting tourmaline and white mica from different settings within the Panasqueira mine. The data show that W and Sn preferentially partition into mica over tourmaline. Tungsten is almost absent in tourmaline and Sn concentration is < 30 ppm. Interestingly, Cu is commonly below the detection limit (< 0.1 ppm) in both phases whereas Zn has relatively high concentrations and partitions preferentially into tourmaline, reaching up to 600 ppm. Other elements such as Li and Rb have high concentrations in white mica (up to 2000 ppm). Boron isotope compositions of white mica yield median values of -16.8, -17.4 and -21.3 ‰ in samples from the greisen, veins and fault zone, respectively. Boron isotopic variations in tourmaline from vein proximal to distal alteration zones (δ11B = -4 to -13 ‰; Codeço et al., 2017) and in mica from the different settings reflect a combination of cooling and a change from fluid-dominated to rock-dominated conditions in the transition between the early and main ore stages. The data support a magmatic fluid source, and a repetition of zoning patterns in early vs. late-stage tourmaline suggests multiple pulses of magmatic-dominated fluids, possibly related to periodic faulting (Foxford et al., 2000). This study highlights the potential of combining tourmaline and white mica geochemistry to trace the hydrothermal fluid composition and source in W-Sn deposits.

References:
Lithospheric structure of Sri Lanka: First large-scale study revealing seismic structure beneath the island – ambient noise Rayleigh wave tomography

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Little is known about the seismic structure of Sri Lanka. Until mid 2016, only three permanent stations were operating on the island. The Geological Survey and Mines Bureau of Sri Lanka and the German Research Centre for Geosciences installed and maintained the first temporary broadband seismic network on the island, consisting of 30 stations running for a period of 13 months in 2016-2017. Fourteen stations form a linear profile perpendicular to the strike of the geological units, the remaining 16 stations are distributed across the island. This deployment layout is optimized for analysis of seismic properties of the crust and mantle lithosphere of Sri Lanka. The aim of this study is to shed light on the crustal and upper mantle structure beneath Sri Lanka in the context of Gondwanaland’s assembly and break-up. We will present the results of Rayleigh surface wave dispersion tomography from ambient noise correlation. These will be supplemented by receiver functions and will be jointly inverted using a Bayesian approach.
Numerical investigation of cyclic hydraulic stimulation and related induced seismicity in Pohang fractured geothermal reservoir

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6.2 - Geothermal Energy Systems

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Understanding processes that control induced seismicity during fluid injection in naturally fractured geothermal reservoirs is in focus of recent research projects about Enhanced Geothermal Systems (EGS). In this study we investigate numerically the flow rate controlled cyclic stimulation experiment performed in August 2017 at the Pohang EGS site using the finite element code FRACMAN. This so-called soft stimulation method aims to increase permeability while reducing the risk of inducing larger seismic events. FRACMAN uses the Discrete Fracture Network (DFN) approach that combines continuum and discontinuum geomechanics. It enables studying hydro-mechanical processes and investigating main characteristics of induced seismicity such as spatial evolution of events and their moment magnitude in relation to injected fluid volume in three dimensions. The results of the field tests suggest that the hydraulic communication between the injection and production wells, PX-1 and PX-2, is limited. The numerical analysis contributes to understanding the apparently structurally-controlled natural compartmentalisation of the fractured reservoir. The code was also used for predicting the relationship between fluid injection volume and spatial extent of generated or reactivated fractures, i.e. the stimulated reservoir volume. This analysis enables investigating pore pressure distribution as stimulation proceeds. The generated DFN model at target depth will also be used for a future study as an input for distribution of pre-existing fractures for hydro-mechanically coupled analysis using the Particle Flow Code (PFC). The analysis and predictions of two different numerical models will allow different injection strategies to be investigated to design an optimal stimulation procedure ahead of further field application.
3D structural model of the Sea of Marmara

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6.1 - Basin Modelling

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The North Anatolian Fault Zone (NAFZ) is one of the most famous active strike-slip fault system which is plate boundary between the Anatolian block and the Eurasian plate. The relative plate motion is about 2.5 [cm/a] and the NAFZ has a length of 1100 km. In its western part, the fault cut through the Sea of Marmara. In this area, basins have been evolving due to the NAFZ in a complex transitional setting. This region represents a seismic gap in the NAFZ where is close to the Megacity of Istanbul with more than 12 million inhabitants. Comprehension and detailed description of the geological structure in the Sea of Marmara are essential keys to understanding the tectonic processes and geodynamic evolution. In particular, the structural setting is probably the control for segmentation of the seismic faults and would determine the maximum possible earthquake magnitude to be expected south of Istanbul in the seismic gap east of the Bay of Izmit where 1999 the last major earthquake hit the region and which has not ruptured since 1766 over a length of app. 150 km. In this study, we integrate different geological and geophysical data such as existing structural models, well data, seismic observations and gravity to build a new 3D lithospheric-scale structural model which is additionally constrained by 3D gravity modeling. The 3D gravity field indicates significant density heterogeneities in the crystalline crust. We have tested different crustal configurations to find the best fit to the observed gravity field. The final 3D structural model suggests that the gravitational anomalies are mostly due to the density contrasts in the upper-middle crust rather than due to the presence of a high-density lower crustal body or the Moho depth. The derived density structure indicates lithological heterogeneities within the crust that may result in different rheological behavior along the NAFZ. This could potentially have an impact on the rupture propagation and segmentation of the fault system.
3D density, thermal and compositional model of the Antarctic lithosphere

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In this study, we use an integrative approach combining gravity and tomography data with mineral physics constraints aiming to create a 3D density, temperature and composition model of the Antarctic lithosphere. In the first step, an initial model of the crust based on available seismic, receiver function and tomography data is created. Based on this model, the residual mantle gravity anomalies and residual topography are calculated. In addition, the effect of deep density heterogeneities, which is based on recent global models, is also removed from the residual anomalies. Next, S-wave velocities from two independent tomography models (SL2013sv and AN1-S) are converted to temperature and temperature induced density variations. These density variations are employed to correct the residual fields for the effect of temperature variations in the uppermost mantle. The resulting residual gravity and topography fields are then jointly inverted to obtain a 3D density model of the lithospheric mantle and compositional changes linked to the density changes in cratonic East Antarctica are estimated. On the basis of the new compositional model, a new temperature model is calculated and the scheme repeats until convergence is reached. Our results show a clear distinction between East and West Antarctica in both temperature and density up to a depth of about 200km. The strongest negative compositional density anomalies can be found at a depth of 200km, close to the pole and in the Wilkes Subglacial Basin, along the eastern flank of the Transantarctic Mountains (\(-0.04\,\text{g/cm}^3\)) and in Dronning Maud Land (\(-0.035\,\text{g/cm}^3\)) for the SL2013sv model. The AN1-S model generally yields similar results only with a shift of the density minima towards central East Antarctica. Apart from this general distinction, we also find evidence of smaller scale variations in density both caused by temperature and composition in central East Antarctica, as around the Gamburtsev Subglacial Mountains. Furthermore, the composition analysis yields changes in the Magnesium content of up to $\text{Mg}# \left( 100 \times \frac{\text{Mg}}{\text{Mg}+\text{Fe}} \right) > 92$ within cratonic East Antarctica. Compared to a vertically and horizontally uniform fertile composition with $\text{Mg}# = 89$, this causes an increase in temperature of over $100^\circ\text{C}$. 

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Influence of mineralogy, pressure, temperature and stress on mechanical properties of shale rocks

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4.2 - Geomechanics and Rheology

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The production of hydrocarbons from unconventional reservoirs, like tight shale plays increased tremendously over the past decade. Hydraulic fracturing is a common method to increase the productivity of a well drilled in these reservoirs. Unfortunately, the production rate decreases over time presumably due to fracture healing. The healing rate induced by proppant embedment depends on pressure (p), temperature (T), stress (σ) - conditions and on shale composition. To improve understanding of the influence of these parameters on fracture healing, we conducted constant strain rate experiments (p = 50 - 100 MPa, T = 50 - 125 °C, \( \epsilon' = 5 \times 10^{-4} - 5 \times 10^{-6} \text{s}^{-1} \)) on porous (~ 8 %), quartz - rich (~ 72 vol %) Bowland shale (UK) and on low porosity (~ 3 %), clay - rich (~ 33 vol %) Posidonia shale (GER), deformed perpendicular to bedding and with as-is water content. Bowland shale showed mainly brittle behaviour with predominantly elastic deformation before failure and a high strength (280 - 350 MPa). In contrast, Posidonia shale deformed semibrittle with pronounced inelastic deformation and low peak strength (165 - 220 MPa). For both shale rocks, static Young’s moduli vary between 12 - 18 GPa.

In addition, we performed a series of constant stress tests on both shales at p = 30 - 115 MPa, T = 75 - 150 °C and \( \sigma = 160 - 450 \text{ MPa} \). Samples showed transient (primary) creep with increasing strain rates for increasing temperature and stress and decreasing pressure. An empirical power law in the form of \( \epsilon = A \cdot t^m \) is used to describe the observed relation between inelastic strain (\( \epsilon \)) and time (t), where the constant A is mainly affected by temperature and stress and the exponent m accounts for the influence of pressure. Compared to quartz - rich, strong Bowland shale, the creep behaviour of clay - rich, weak Posidonia shale is much more sensitive to changes in pressure, temperature and stress. Electron microscopy suggests that creep was mainly accommodated by deformation of weak phases (TOC, clay, mica). Our results suggest a low fracture healing rate of Bowland shale, whereas fractures within the Posidonia formation tend to close faster.
Experimental determination of H2 solubility in saline solutions under reservoir conditions

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Emitting huge amounts of carbon dioxide, the burning of fossil energy sources are considered the driving force for global warming. The German energy transition therefore aims at switching from fossil to renewable energy sources and the future energy system will differ notably from the current. The increasing share of renewable energy in the system leads to a highly fluctuating and somewhat unpredictable energy supply. To balance energy supply and demand and to further increase the amount of renewable energy while maintaining security of supply, innovative technologies for large-scale energy storage are needed. One possible solution are power-to-gas techniques, which uses surplus energy of e.g. wind power to produce synthetic gases like hydrogen. These gases can then be flexibly stored in the subsurface at required scale. Contrary to geological storage of natural gas, which is a mature technology since decades, geological storage of hydrogen is only done at very few places worldwide and is still in its initial stage of development. As for natural gas, hydrogen storage options include salt caverns and porous rocks. For a reliable assessment of the different storage options, fundamental data like hydrogen solubility in formation fluids or hydrogen diffusion rates for the different reservoir and cap rocks at the respective pressure and temperature conditions are needed but to a large extend are still lacking. Within the running projects Energy System 2050 and H2_ReacT, laboratory experiments have been performed to derive internally consistent data on H2 solubility in saline solutions under reservoir conditions. The experiment were performed in an autoclave capable of high pressures and temperatures and covered conditions from 25 to 150 °C, pressure up to 200 bar and salinities up to salt saturation within the KCl- and NaCl-H2O systems. The gained results are compared with theoretical solubility models based on available thermodynamic data. The comparison clearly shows that the so far available thermodynamic data and models are not capable to reproduce the experimental results. The newly derived solubility data will be used to update and improve the thermodynamic data bases and also for subsequent modelling. Further investigations will study potential fluid-rock interactions of mineral separates as well as rock samples with hydrogen and brine. A new experimental set-up including hydrogen tight diffusion cells is drafted to study and determine permeability and diffusion rates of hydrogen through potential cap rocks like salt rock or claystone.
Rheological properties of a natural subduction zone interface: insights from numerical modelling

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The physical nature of plate locking and its relation to surface deformation patterns at different time scales (e.g. GPS displacements during the seismic cycle) can be better understood by determining the rheological parameters of the subduction interface. However, since direct rheological measurements are not possible, numerical modelling helps determine the effective rheological parameters of the subduction interface. Using the open source finite element code pTatin, we implemented a 2D model to simulate simple shearing of a two-phase medium in order to quantify the effect of heterogeneous rheology on stress and strain localization. This heterogeneity results from field observations, where shear zone outcrops are often composites of multiple phases: strong crustal blocks embedded within a sedimentary and/or serpentinized matrix have been reported for several exhumed subduction zones.

We tested several boundary conditions that mimic simple shear and chose the one that best describes the Grigg’s type simple shear experiments. Preliminary results show different strain accumulation and strength in the models, depending on the block-to-matrix ratio. We applied our method to outcrop scale block-in-matrix geometries and by testing the same geometry at different P-T conditions, and therefore depth; we expect to provide effective friction and viscosity estimates of a natural interface. Using these effective parameters as input into seismic cycle models could help evaluate the possible effect of field heterogeneities on the slip behaviour of the plate interface.
Changes in paleo erosion rates during fluvial aggradation in the Yamuna catchment, northern India

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The study of fluvial fill terraces provides information about the tectonic and climatic history and is fundamental for understanding landscape evolution. Deposition of fluvial sediments within actively eroding mountain ranges could result from changes in tectonic uplift rates, climatic conditions and/or surface processes. However, reconstructions of such changes from valley fills are often ambiguous and based on correlating such chronologies with regional climatic changes. In this study, we present "in situ" cosmogenic 10Be derived paleo erosion rates from sand and pebbles, combined with field observations from a 120 m exposed fluvial river terrace in the Yamuna catchment, northern India. The Yamuna catchment is a relatively small (648 km²) and steep (mean slope ~29°) catchment that exposes different lithologies from the Lesser (LHS) and High Himalayan sequences (HHS). Infrared stimulated luminescence (IRSL) measurements of samples from the base and near the top of the river terrace indicate an aggradation period that was ongoing between 29.9 ± 2.5 ka and 23.2 ± 3.5 ka and suggest a deposition during glacial time. 10Be results from terrace sand indicate paleo erosion rates between 1.5 ± 0.1 mm a⁻¹ and 2.3 ± 0.2 mm a⁻¹ that were higher than modern river-sediment based erosion rates of 1.1 ± 0.1 mm a⁻¹. The differences between modern and paleo erosion rates could be caused by: (1) different uplift rates within the LHS and the HHS, (2) the influence of glaciation by input of subglacial material which would lower the 10Be concentration and (3) the erosional efficiency of periglacial processes during colder periods. Interestingly, paleo erosion rates derived from terrace pebbles of LHS origin were lower (0.9 ± 0.1 mm a⁻¹ to 1.1 ± 0.1 mm a⁻¹) but higher for pebbles of HHS origin (2.4 ± 0.3 mm a⁻¹ to 4. ± 0.5 mm a⁻¹). These differences in paleo erosion rates from pebbles of LHS and HHS origin clearly document steep spatial gradients in paleo erosion rates and we currently focus on quantifying potential differences due to the above scenarios with simple models.
Applying sea-level indicators to validate reconstructions of relative sea level during the last glacial termination phase

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Observations of sea-level variations allow the validation of numerical models used to reconstruct past and predict future sea-level change. Sea-level indicators (SLIs) are used as the main source for deriving relative sea level (RSL) variations during previous epochs for which tide-gauge and satellite measurements were yet not available. However, the leveling of an SLI relative to present sea level does not provide a direct measure of former RSL, but only an indication according to the conditions under which the sample was deposited. This information depends on the sample type and on its environment and has to be mapped to RSL by an appropriate transfer function. The respective data has to be extracted by an objective procedure from primary information usually provided in geological or palaeontological literature of different primary focus, quality and detailedness. In addition to the height information, also the precision of dating varies between different indicators and in case of radiocarbon-dated material, a further calibration of the dated age has to be applied. Due to the fact that the uncertainty information cannot be presented by normal distributions, we define likelihood functions which take into account the indicative meaning as available error information. The same strategy is used for the radiocarbon dated samples, where non-linear calibration curve has to be applied, when considering the sample’s metadata, and which results in a non-normal distributed age uncertainty. This procedure is accompanied by applying the visual analytic tool SLIVISU. Depending on the statistical significance, the analyzed SLIs will serve as validation data for the viscoelastic lithosphere and mantle model VILMA. The VILMA model is currently part of the German Paleo-Climate Modelling Initiative PalMod (https://www.palmod.de/en), serving as the solid-earth response in the earth-system models applied in this initiative. This study contributes to the validation of SLIs as proxy data for sea-level reconstructions during the last glacial cycle.
Leads and lags in sedimentation response to Younger Dryas climate change in a three lake cascade in northern Poland

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5.2 - Climate Dynamics and Landscape Evolution

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Lake sedimentation responses to climate change are partly controlled by local catchment morphology and lake basin bathymetry. However, not much is known about the influences of these controlling factors on lake sedimentation and in particular geochemical proxies. Here, we compare high-resolution sedimentological and geochemical proxies (XRF element scanning, stable isotopes, bulk carbon and varve micro-facies) of three partly varved sediment records for their responses to Younger Dryas (YD) climate change. The YD is an ideal time window to study proxy signals in more detail because it represents the latest major and abrupt climate change. Lake Gleboczek (JG), palaeolake Trzechowskie (TRZ) and Lake Czechowskie (JC) were formed by glacial hydrodynamic processes and are located within one catchment composed of mainly outwash plain deposits. The lakes form a cascade-chain. The close proximity of these three lakes ensures that the climate signal was the same for these lakes. We investigate the interval of 13,100 to 11,200 years BP (from the Allerød up to the early Holocene). The lake records are synchronized through well-defined biostratigraphic boundaries (Allerød/YD and YD/ Preboreal) as well as the early Holocene Askja-S Tephra. Varve formation was interrupted during most of the YD in all three lakes, but our results shows that cessation of varve preservation in JG is lagging by approximately 170 years at the onset of the YD in comparison to TRZ and JC. The beginning of varve preservation occurs about 70 years earlier than in JC around the end of YD whereas varves did not appear again in the early Holocene in TRZ. Detailed XRF scanning records indicate a general higher detrital input during the Younger Dryas in all three lakes. However, asynchronous changes in the XRF element records and stable isotope data around the main climatic shifts in these three lakes demonstrate the influence of local lake and catchment morphology on sedimentation.

References:
The lithospheric strength controls on foreland deformation patterns: Insights from numerical models

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2.5 - Geodynamical Modelling

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Deformation in foreland fold-thrust belts adjacent to the orogen wedge commonly includes shallow thin-skinned and deep thick-skinned structures, which are distinguished by the basement-involved shortening. A good example is the N-S oriented deformation diversity in central Andean Orogen including a broad thin-skinned Sub-Andean thrust belt in the foreland of Altiplano Plateau and the thick-skinned deformation in the Santa Barbara system in south Puna foreland. Previous studies suggested that different deformation styles might be controlled by strength reduction of the lithosphere on which the confining pressure and temperature strongly depending on the lithosphere and crust thickness, compositions and fluid content, strain rate, as well as sedimentary loads and strength of sediments have influence. However, the exact nature of lithospheric strength variations controlling the foreland deformation is not well understood. This study uses high-resolution numerical models to investigate these factors. The models show that the pure shear shortening occurs when the lithosphere under the orogen is thicker (stronger) than the foreland lithosphere with the same thick crust in the orogen-foreland system. When the orogenic lithosphere is weaker with either thinner lithosphere or thicker crust depth, by contrast, the foreland crust underthrusts beneath the orogen in simple shear shortening mode. The thick-skinned structure results mostly from the pure shear shortening, but may also take place during limited foreland underthrusting when the mechanically weak sedimentary layer is absent in foreland. A transition to thin-skinned thrusting requires both mechanically weak foreland sediments and the process of foreland underthrusting. The thickness of orogenic crust plays an important role in forming the thin-skinned structure; the amount of deformation is increasing with the orogenic crust thickening. The factors of the wet/dry composition of the lower crust and mantle and strain rate have a small effect on the foreland deformation. The high-resolution models are consistent with previous numerical studies about foreland deformation of the Altiplano-Puna Plateau as well as the thin-skinned wedge in the foreland of Southern Canadian Rocky Mountains.
Eruptive events in 2016-2017 at Bezymianny volcano, Kamchatka, measured by high-resolution TerraSAR-X and photogrammetric data

René Mania

Eruptive events in 2016-2017 at Bezymianny volcano, Kamchatka, measured by high-resolution TerraSAR-X and photogrammetric data

René Mania

Lava dome development is closely tied with volcanic explosions and destructive pyroclastic flows that constitute vital hazards in many volcanically active regions. Thus, close monitoring of dome building processes is crucial, but often limited to low data resolution, hazardous access and poor weather conditions. However, satellite Synthetic Aperture Radar (SAR) data enables sustained and precise detection and quantification of ground motion. Here, we investigate the explosive activity of the Bezymianny stratovolcano on the Kamchatka peninsula, Russia, in 2016-2017 by employing TerraSAR-X acquisitions in high resolution spotlight mode. We analyze systematic changes occurring in consecutive SAR scenes by composite image analysis, and quantify deformation by feature tracking algorithms, to determine stages and directions of extrusion and eruption. We could identify three well defined extrusive episodes succeeded by eruptions with increasing strengths. While the first (12/2016) was preceded by plug extrusion within the summit crater, the second (03/2017) and third (06/2017) eruption were also accompanied by deformation of the flanks outside the summit crater and continuous spreading of lava flows. The last and strongest explosion yielded in a new summit crater morphology and partial fill-up of the 1956 crater moat with pyroclastic material. We complement our analysis with webcam imagery observing the eastern flank of Bezymianny, and with seismic records, both of which comply with satellite-derived dome growth and eruption history. The integration of optical and SAR data in our work allows identifying precursory deformation, and helps understanding geomorphologic as well as structural processes culminating in explosive eruptions at dome building volcanoes.
First results of 3D VSP imaging with DAS technology at the geothermal research site Groß Schönebeck /Germany

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6.2 - Geothermal Energy Systems

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In early 2017, a high-resolution 3D reflection seismic and an extended Vertical Seismic Profile (VSP) survey were conducted at the Groß Schönebeck in-situ geothermal laboratory situated 50 km northeast of Berlin. The site offers geological conditions typical for a broad part of Northern Europe. Therefore, the gained knowledge can be generalized to the region or applied to other regions with similar geological conditions. The target reservoir zone is represented by siliciclastic sediments and volcanic rocks of Lower Permian (Rotliegend) age, and overlain by Zechstein salt. The 3D surface seismics covers an area of 8 km x 8 km with a focus on reservoir depths of 4000 to 4300 m to improve the comprehension of the geological structures (specifically the spatial distribution of the fault systems). The main objectives for the 3D VSP survey were to derive a detailed imaging around the existing boreholes, to improve the seismic interpretation in the reservoir interval (horizon allocations, stratification, litho-units, spatial distribution of reflection interfaces) and to map potential occurrences of free gas and fractures generated by hydraulic stimulation. Results of both methods will be combined and support the planning of a new research well at the site. The VSP measurements were performed in the two 4.3 km deep wells E GrSk 3/90 and Gt GrSk 4/05 using Distributed Acoustic Sensing (DAS) technology on wireline cable with a channel spacing of 5 m. DAS is a relatively young method of data acquisition, which allows to use a fiber optic cable as an array of sensors for the measurement of particle motion. This method measures the strain variation on the fiber to characterize the acoustic signal. Limitations of the method currently include e.g. higher noise levels, uncertainty of depth determination, and directional dependence of the amplitude response on the angle of incidence. The VSP datasets were recorded during four days with one day for pre-survey start-up tests and three days of data acquisition. The 61 vibro source points (VP) were arranged in a spiral pattern around the target area, with offsets of 200 to 2000 m. Datasets from all source points were processed uniformly, followed by Kirchhoff depth migration. During data analysis, a strong coherent noise was discovered, possibly caused by poor coupling of the sensor cable to the borehole casing. A time-frequency domain noise attenuation procedure was applied in affected depth intervals, and resulted in improved image quality for the reservoir analysis. DAS VSP images provide higher vertical and lateral resolution than surface seismics in the target zone. Reaching a depth of greater than 4.2 km, it has moreover been proven the first time that such depths can be surveyed with DAS, allowing for widespread future applications.
Steady state or transient - the thermal state of retro-arc foreland basins

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6.1 - Basin Modelling

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Numerical simulations used for predicting the lithospheric-scale temperature variations in the subsurface of sedimentary basins widely assume that the system is in a thermal steady state. Whilst this assumption is applicable to stable continental interiors, it must be assessed whether it can be applied to recent retro-arc foreland basins. Such basins are subject to the transient processes of subduction, shear heating, mountain building and melt formation that impact the thermal field. We aim to assess by means of numerical simulations how the thermal field of retro-arc foreland basins is influenced spatially and temporally by subduction of oceanic crust. Therefore, we set up two-dimensional models including cratonic and oceanic lithosphere. Starting from a steady-state conductive thermal field we convect the oceanic lithosphere along a predefined subduction channel and continuously monitor the evolution of the thermal field in the foreland. This procedure allows to assess how, and to what extent, the age of the oceanic lithosphere, craton thickness, shear heating and convergence rate alter the thermal field in the foreland.
The link between megathrust segmentation and upper plate faulting along the N-Chilean subduction system

Jana Mittelstaedt
4.1 - Lithosphere Dynamics

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The 1000 km long Atacama Fault System (AFS) is a trench parallel fault system, situated in the forearc of Northern Chile, one of the tectonically most active continental margins on earth. Compiling data from high resolution satellite pictures, seismic catalogues and field investigations, we have created an overview map of the upper plate faulting. Activity of the faults is determined in the following order: (1) literature review and field data, (2) crosscutting relationship with Pleistocene features, i.e. paleochannels and alluvial fans, (3) occurrence of crack fields in the hanging block and (4) geomorphic indicators. Along the Atacama Fault Zone activity is closely coupled to the underlying megathrust and its segmentation. One of these segment boundaries has been identified at Mejillones Peninsula by Victor et al. 2011. Defined by an abrupt cutoff of upper plate activity at the lower end of the Iquique rupture (2012), we determined a second segment boundary. This boundary coincides with a prominent EW thrust fault (Aguierre Fault), indicating trench-parallel shortening.
Climatic and environmental conditions during the Younger Dryas-Holocene Transition in Lake Gościaż

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5.2 - Climate Dynamics and Landscape Evolution

The termination of the last deglaciation in the northern hemisphere was marked by the abrupt Younger Dryas (YD) cold event. This abrupt event provides valuable insights into the sensitivity of the climate system, especially into high-resolution climate archives, like annually laminated (varved) lake sediments. Lake Gościaż (central Poland) offers one of the longest and best-preserved varved lake sediment sequences in Europe, ideal for the climatic and environmental reconstruction of the YD. Therefore, three new parallel sediment cores have been obtained to re-investigate this iconic record. A high-resolution methodological approach was applied, combining microfacies data with µ-XRF element core scanning, which was complemented by organic carbon, carbonate and stable oxygen and carbon isotopes analyses. Due to a major slump in our cores, the Allerød/YD transition is not recovered and the varved record starts in the early YD. The YD/Holocene transition is defined by means of biostratigraphy which correlates well to previously investigated cores. Our new floating varve chronology comprises 1346 ± 14 varve years reaching from the early YD into the early Holocene. Detailed microfacies analyses revealed two different varve microfacies types for the YD and Holocene. The YD is characterized by sublayers of resuspended material, calcite and diatom frustules. The detrital flux is slightly increased, but does not form a distinct sublayer. In contrast, the Holocene varves are less complex and mainly consist of calcite and organic sublayers. Discrete diatom sublayers are not formed, detrital material is almost completely absent, and resuspension is clearly decreased. The sharp transition in varve microfacies occurred 47 varves after the biostratigraphically defined onset of the Holocene. The distinctly larger interannual variability in varve microfacies during the YD indicates less stable climate conditions than in the Holocene. In more general, the YD/Holocene transition is characterized by successive shifts of different proxies within at most 160 varve years. Chemical element variations show either a single sharp shift or a sequence of oscillations, occurring around the biostratigraphic boundary. δ18Ocarb values increase and δ13Ccarb values decrease within 37-62 varves, commencing roughly at the biostratigraphic boundary and ending after the change in microfacies. This study is a contribution to scientific project financed by the National Science Centre, Poland – No. UMO- 2015/19/B/ST10/03039.
Comparative studies of Traveling Ionospheric Disturbances (TID) at North, South and Equatorial African Continent

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1.1 - Space Geodetic Techniques

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This study presents for the first time, the results of medium-scale travelling ionospheric disturbance (MSTID) observations that were obtained using Global Positioning System - Total Electron Content (GPS-TEC) data obtained from the arrays of GPS ground-based stations situated at the three geographical sectors (southern hemisphere (SH), northern hemisphere (NH) and equatorial ionization anomaly (EIA) zone) of African region, with each array in triangle configuration. MSTID are wavelike fluctuations of the electron density induced by atmospheric gravity waves (AGW). In this study, we consider selected days of moderate and below moderate geomagnetic conditions ($k_p < 4$), during different solar activity years; i.e. 2008 (low solar year with average sunspot number ($R_z$) of 4), 2014 (high solar year with $R_z = 113$) and 2016 (moderate solar year with $R_z = 41$). The sporadic MSTID structures with a varying magnitude which are latitudinal dependent were detected in all the sectors as observed from the GPS-TEC data. Some propagation characteristics of the MSTID such as the percentage occurrence rate and periods were estimated by applying wavelet theory on the GPS-TEC perturbation results. Statistical angle of arrival and Doppler method for GPS interferometry (SADM-GPS) algorithm was employed, the mean horizontal velocity (MHV) and wavelength where obtained for the selected days. The average (2008, 2014 and 2016) results for MSTID percentage occurrence rate (POR), dominant periods and MHV were obtained to be: (~33%, 69.0 minutes (mins), and ~164 min/sec), (~26%, 46.3 mins, and ~172 min/sec) and (~31%, 46.0 mins, and ~134 min/sec) for SH, NH and EIA respectively. In total, the characteristics result show that MSTID events vary with latitude in each sector in terms of regional comparison. The POR act as an indirect index to indicate the AGW dominance magnitude at various sector of Africa region. Further result reveals the MSTIDs propagation direction and full details of POR.
Electromagnetic characteristics of ENSO

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1.3 - Earth System Modelling

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The motion of electrically conducting sea water through Earth's magnetic field induces secondary electromagnetic fields. Due to its periodicity, the oceanic tidal-induced magnetic field is easily separable from magnetic field measurements and therefore detectable. These tidal-induced signatures in the electromagnetic fields are also sensitive to changes in oceanic temperature and salinity distributions. We investigate the impact of oceanic heat and salinity changes related to the El Niño/Southern Oscillation (ENSO) on oceanic tidal-induced magnetic fields. Hydrographic data containing characteristic ENSO dynamics have been derived from a coupled ocean-atmosphere simulation covering a period of 50 years. By applying a 3D induction model the corresponding tidal-induced magnetic signals have been calculated. By means of the Oceanic Niño Index (ONI), based on sea surface temperature anomalies, and the Magnetic Niño Index (MaNI), based on anomalies in the oceanic tidal-induced magnetic field, we demonstrate that evidence of developing ENSO events are found in the oceanic magnetic field statistically 4 months earlier than in sea surface temperatures. The analysis of subsurfaces processes incorporated into the MaNI and spatio-temporal distributions of electromagnetic anomalies is used to increase this lead even further.
Advances in characterizing the ring current magnetic effect at ground level

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Electric current systems in the magnetosphere are the strongest external source of the superposed magnetic field measured on ground. The most prominent one close to Earth is the ring current which is mainly carried by 10–200 keV ions (H+, He+, O+) drifting westward around Earth at 2–7 RE in the magnetic equatorial plane. The ion distribution is generally not uniform with respect to magnetic local time (MLT), causing the current to be stronger at dusk and weaker at dawn. The current’s global strength can be monitored continuously via ground-based magnetometers at low and mid latitudes, which record a characteristic decrease in the horizontal component of the main field. This is exploited in the derivation of the hourly Dst index and the one minute resolved SYM/ASY indices using observatory measurements that date back to 1957 and 1981, respectively. They provide relative strengths of the part of the current that is symmetric (Dst, SYM) and the one that is asymmetric (ASY) in MLT. However, these indices naturally fail to adequately characterize the magnetospheric field at a particular place, especially so at geomagnetically active times. Our work concentrates on a) producing an index that measures the symmetric ring current strength back to 1900 and b) exploring empirical ways to model the MLT dependent magnetospheric field signature under geomagnetically disturbed conditions. The first result was an annual version of the long-term index called AMC (Annual Magnetospheric Currents) that is based on observatory measurements from which a core field model (COV-OBS) and estimates of the static crustal magnetic contributions have been subtracted. Aside from the extended time period, AMC provides a stable baseline and a realistic absolute level of the disturbance field which is not the case for any other currently existing index. AMC provides a means of distinguishing between external variations and secular variation on decadal time scales. The hourly resolved index, HMC, is currently under development and will significantly increase the range of applications, including a quantitative characterization of geomagnetic storms in the early 20th century. Based on a selection of geomagnetic storms in the second half of the 20th century we further plan to derive an MLT resolved model of the asymmetric current strength from magnetic observatory measurements and concurrent solar wind/IMF properties in conjunction with HMC.
On the field-aligned currents related to plasma depletions in the equatorial ionosphere - New insights from the Swarm mission

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2.3 - Geomagnetism

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Right after sunset, structures of depleted plasma emerge from the bottom side of the ionosphere causing disturbances in navigation and communication systems. The advance in their understanding, especially of their electrodynamics, is relevant for their forecast and mitigation of their impact. Currently, the study of the field-aligned currents (FAC) flowing at the edges of equatorial plasma depletions (EPD) is based on theoretical assumptions. In this work, electron density and magnetic field data from the Swarm mission are used to infer the orientation of the FAC. Contrary to expectations, the FAC turn out to flow from one magnetic hemisphere to the other rather than away from and towards the dip equator, as the theoretical considerations suggested. Already two years of Swarm measurements have revealed a distinct seasonal and longitudinal variation in the FAC orientation. These new observations are suggested to be due to the hemispherical asymmetry of ionospheric conductivity driven mainly by the seasonal variability of neutral winds and the longitudinal variability of the geomagnetic field strength.
Forecasting Pluvial Flood Loss

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Pluvial flood events of different magnitudes including smaller events in Amsterdam 2014 or Berlin 2017 and large events such as in Copenhagen 2011, Beijing 2012 or Houston, TX 2017 have caused overall economic losses in the range of tens of billion Euros over the last decade. Unlike riverine flooding, these floods are directly caused by storm events with high rainfall rates well above the design levels of urban drainage systems, which lead to inundation of streets and buildings before the storm water reaches a watercourse. A projected increase in frequency and intensity of heavy rainfall events in many areas around the globe and an ongoing urbanization may further increase pluvial flood losses in the future. For an efficient risk assessment and adaptation to pluvial floods, a quantification of the pluvial flood risk is needed. So far most studies have been focusing on the hazard component, while only few models have been developed to analyze the vulnerabilities associated with pluvial floods. These models usually use simple water level- or rainfall-loss functions and come with very high uncertainties. To quantify these uncertainties and improve the loss estimation, we present a probabilistic multi-variate loss estimation model for pluvial floods based on empirical data. The model was developed in a two-step process using a machine learning approach and a comprehensive database comprising 783 records of direct damage to private households. The data was gathered through telephone surveys with affected households after four different pluvial flood events in Germany between 2005 and 2014. In a first step, linear and non-linear machine learning algorithms, such as tree-based and penalized regression models were used to identify the most important loss influencing factors among a set of 57 candidate variables. The variables cover hydrological and hydraulic aspects, early warning, precaution, building characteristics and the socio-economic status of the affected households. In a second step, the most important loss influencing variables were used to develop a probabilistic multi-variate pluvial flood loss estimation model using a Bayesian beta regression model. To account for cases, where high individual coping capacities and low water levels did not lead to any direct building damage, a zero-inflation component was added to the beta regression model. Probabilistic loss estimates are made through Bayesian inference using Markov Chain Monte Carlo (MCMC) sampling. In comparison with deterministic and ensemble loss estimation models using the same data, it is shown that Bayesian loss models can considerably improve the accuracy and reliability of loss estimates. With the ability to cope with incomplete information, implementation of expert knowledge through priors, as well as inherently providing quantitative uncertainty information, multi-variate Bayesian loss models offer a promising new framework for risk assessment of pluvial floods.
Interseismic deformation transients and precursory phenomena: Insights from stick-slip experiments with a granular fault zone

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4.1 - Lithosphere Dynamics

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The release of stress in the lithosphere along active faults shows a wide range of behaviors spanning several spatial and temporal scales. It ranges from short-term localized slip via aseismic slip transients to long-term distributed slip along large fault zones. A single fault can show several behaviors in a complementary manner often synchronized in time or space. To study the multiscale fault slip with a focus on interseismic deformation transients we apply a simplified analog experiment using a rate-and-state-dependent frictional granular material deformed in a ring shear tester. The analog model is able to show the full spectrum of natural slip behaviors including transient creep and slow slip events superimposed on regular stick-slip cycles (analog seismic cycles). Analog fault slip is systematically controlled by extrinsic parameters such as the system stiffness, normal load on the fault, and loading rate. We observe two peculiar features in our analog model: (1) Absence of transients in the final stage of the stick-slip cycle ("preseismic gap") and (2) "scale gaps" separating small slow events from large fast events. Concurrent micromechanical processes, such as dilation, breakdown of force chains and granular packaging affect the frictional properties of the experimental fault zone and control interseismic strengthening and coseismic weakening. Additionally, creep and slip transients have a strong effect on the predictability of stress drops and recurrence times. Based on the strong kinematic similarity between our fault analog and natural faults, our observations may set important constraints for time-dependent seismic hazard models along single faults.
Depositional Environment Interpretation and Organofacies Characterization for Yacoraite Fm, Salta Basin - Argentina

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The Yacoraite Formation (Maastrichtian-Danian) is one of the main source rocks in North-West Argentina in the sedimentary basins in Salta and Jujuy provinces. It was deposited following Lower Cretaceous rifting, representing the last Cretaceous marine ingression although locally evidence has been found for lacustrine depositional conditions. Here we show preliminary results for depositional environment characterization for Tres Cruces and Metan-Alemania subbasins, based on organic geochemistry of rock samples and their extracts. Depending on its depositional environment, the Yacoraite Formation exhibits a wide range of organic content varying from poor up to rich (up to 7% TOC). Its organofacies are mainly represented by kerogen type II and II/III with low sulphur content, indicative for marine organic matter. The kerogen type III observed in several samples indicates input of terrestrial organic matter probably related to periods of sea level fall. Biomarker distribution in organic matter like the relative abundance of C27-C29 steranes have been widely used to differentiate between marine, lacustrine or terrestrial depositional environments. The sterane distribution of our samples indicates an open marine depositional environment for Yacoraite Fm. In addition to the shale dominated rock samples, two stromatolite samples from the same formation have been analyzed. Stromatolites are carbonate rocks commonly formed by biomineralization in shallow water. Sterane biomarker abundance indicates deposition in an marine environment. However, previous studies have shown that diatoms, certain alga and cyanobacteria can enhance C29 sterane abundance which can lead to a misinterpretation of the depositional environment. For more precise environment interpretation a comparison with other parameters is intended. In addition to the depositional environment, the oxygen conditions during organic matter deposition are of interest. The analyzed hopane biomarkers indicate anoxic conditions during Yacoraite Fm deposition favoring organic matter preservation. In this environment, the dibenzothiophene/phenanthrene ratio indicates low sulphate ion concentrations which is in agreement with low dimethylthiophene abundance identified by Py-GC. While studied shales of Yacoraite Fm have the potential to generate mixtures of P-N-A oils with variable wax content and some gas or condensates, the stromatolites produce P-N-A oils with low waxy content. Its kerogen, depending on depth of burial in the different subbasins is thermally immature (<0.5% Ro) or thermally mature in oil window (0.5 - 1%Ro). Further complementary biomarker and petrography analysis are necessary to refine the understanding of the depositional environment of Yacoraite Fm and resolve apparently contradictory results shown here.
Continuous high resolution gravity measurements at a geothermal field in Northern Iceland

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6.2 - Geothermal Energy Systems

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In December 2017, three superconducting gravity meters (iGrav006, iGrav015 and iGrav032) were installed in the Theistareykir geothermal field in Northeast Iceland. Together with two gPhone relative gravity meters (gPhone061 and gPhone128), subsurface mass changes from production and injection of fluids in the course of the operation of the new power plant that started operation in October 2017 will be monitored for at least one year. Prior to the Iceland installation, all gravity meters were co-located for simultaneous measurements at the gravimetric observatory J9 in Strasbourg, France. The obtained data were used for instrumental calibration, comparison of noise levels and tidal analysis. During transport from Strasbourg to the geothermal site in Iceland, the superconducting gravity meters were kept at their 4K operating temperature. This way, the time-consuming cool-down process of the iGravs as well as the generation of high initial drift rates could be avoided. The measuring sites in Theistareykir were set up close to the geothermal production and injection wells. Additionally, one site is located outside the geothermal field, for reference measurements that are unaffected by the activities of the power plant. At each site, a set of physical parameters which influence the local gravity signal are measured. This includes the monitoring of soil moisture, groundwater level, and snow height. Moreover, snow weight and snow water equivalent are measured at the production site. Here, we present the results of the unique intercomparison of three superconducting gravity meters and two gPhones at Strasbourg and the first time series obtained at the geothermal site in Iceland. An initial interpretation of the gravity variations with regard to the geothermal activities and the hydro-metrological dynamics is given.
Bayesian Network based mesoscale flood loss modeling with BN-FLEMO in the upper Danube basin

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The frequent occurrence of large river floods and the resulting economic loss emphasize the need for risk-oriented flood management approaches. Flood loss estimation on the mesoscale is an integral component for the implementation of the EU Floods Directive and an indispensable tool for the insurance and reinsurance industry to calculate premiums and define solvency requirements. Despite this important role, flood loss models often rely on simple water-depth to damage relations and usually neglect other flood intensity metrics and other relevant factors describing the resistance characteristic. Further, flood loss predictions are associated with large uncertainty. We approach this problem by proposing the multi-variable probabilistic loss model BN-FLEMO that allows for the consideration of multiple predictor variables and the quantification of uncertainties in model outputs. BN-FLEMO estimates the relative loss to residential buildings in dependence on flood experience of the population, precautionary measures, building area, return period, duration and water depth. The model is based on empirical data and has been validated in a number of case studies throughout Europe. The focus of this contribution is on the application of the model within a continuous long-term simulation, over a period of 10,000 years, of the German part of the Danube for current climate conditions. This simulation builds on the outputs of a model chain consisting of a stochastic weather generator, a hydrological model, and a hydrodynamic model. Within this set-up, large-scale risk assessment is investigated under consideration of uncertainties regarding the flood hazard, described via a stochastic event set and uncertainty of flood loss estimates, which is represented by the conditional probability distribution of relative flood loss within the Bayesian Network.
Optimized Experimental Network Design for Earthquake Location Problems: applications to geothermal and volcanic field seismic networks

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6.2 - Geothermal Energy Systems

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We propose a network optimization scheme for designing and qualifying local and regional microseismic monitoring arrays. Our optimization routine is based on the traditional minimization of the volume error ellipsoid of the linearized earthquake location problem (D-criterion) but with the twist of a sequential design procedure. Seismic stations are added one by one to constrain the locations of multiple hypothetic earthquakes with varying attenuation levels. The sequential approach significantly reduces design computation efforts and allows the analysis for benefit/cost relations. Cost curves are computed for all hypothetic events to reveal the minimum optimal number of stations given specific design experiment objectives. In addition sequential design allows for easier in the field seismic station deployment as one can quickly compute one by one the next station positions and account for the latest placement variations if it had not been possible to place a seismometer precisely at a planned location. The routine was first tested on three test design experiments obtaining resulting network geometries similar to those of the classical simulated annealing approach. Later we used the routine to augment an existing seismic network for monitoring microseismicity in a geothermal field in NE Iceland (Theistareykir). The resulting 23 station network will become the backbone of a reservoir behavior and exploitation activity study. Hypothetic event locations and magnitude relations were taken from a previous regional seismicity study and coincide with geothermal injection and production areas. Sensitivities were calculated with a known 1D velocity model profile using a finite-difference back-ray tracer, and body wave amplitudes were computed from known local magnitude relations. Finally expected earthquake location accuracies were computed via multiple Monte-Carlo experiments. The design routine was used to qualify an existing seismic network located SW Iceland (Reykjanes) and its picking selection. We explored the possibility of adding few picks of strategic stations with benefits and accuracies considerably enhanced. Similarly, the seismic array was selectively reduced and benefit and expected accuracies were quantified to observe whether costs could have been optimized had a previous network design experiment been performed. Overall the technique hereby explored proves a quick and flexible tool for designing and qualifying networks for many applications at various scales.
Where do 10Be-derived denudation rates depend on grain size?

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3.3 - Earth Surface Geochemistry

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In-situ cosmogenic 10Be is a frequently used method to measure catchment average denudation rates from river sediment. Commonly, the sand fraction (<1 mm) is used to determine denudation rates. However, some studies suggest 10Be concentrations may vary between different grain sizes. A typical explanation for such phenomena invokes mass wasting processes that excavate coarser grains from greater depth where 10Be concentrations are lower. Using the sand fraction (<1 mm), with higher 10Be concentrations, could thus introduce a denudation rate bias in mass wasting dominated catchments. It is, therefore, important to investigate grain size dependent 10Be concentrations and their potential climatic, tectonic and lithological causes. This study consists of two parts: a controlled grain size study, in which we focus on the effect of precipitation only, and a global grain size compilation, in which we focus on the effects of precipitation, tectonics and lithology. In the controlled grain size study we measured 10Be concentrations in 7 grain size fractions sampled in 4 catchments located on a precipitation gradient (~13 to ~1200 mm/yr) in the Coastal Cordillera of central Chile. The catchments share similar topographic and lithological conditions. Despite the large precipitation gradient, the variation in 10Be concentrations in grain sizes was small and grain size trends were weak. The global compilation includes 95 sample sets covering different lithologies and a large gradient in climatic and tectonic conditions. Results revealed minor differences in 10Be concentrations between grain sizes in shallow (<15°) and slowly eroding catchments, whereas steep (>15°) and fast eroding catchments show distinctly lower 10Be concentrations in coarse grains. The effects of precipitation and lithology are less evident in the global compilation. The results reveal that the variation in denudation rates, as result of grain size dependent 10Be concentrations, is small in shallow and slowly eroding catchments and large in steep and fast eroding catchments. The likelihood of introducing a bias, by sampling the sand fraction, is therefore higher in steep and fast eroding landscapes. We conclude that climate and lithology have a weak control on grain size dependent 10Be concentrations. With the use of grain size distribution models we will further investigate the variation in denudation rates in different landscape settings. Additionally, we will evaluate the causes of grain size dependent 10Be concentrations.
Downscaling GOME-2 far-red solar-induced chlorophyll fluorescence from canopy to photosystem

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Satellite retrieval of solar-induced chlorophyll fluorescence (SIF) is a promising tool for directly monitoring photosynthesis of terrestrial vegetation from space. However, remotely-sensed SIF is sensitive to solar-viewing geometry and is only a fraction of photosystem-emitted SIF, due to multiple scattering/absorption of SIF within the canopy. We applied a machine learning approach to downscale GOME-2 far-red solar-induced chlorophyll fluorescence from canopy level to photosystem level in order to better understand the relationship between SIF and photosynthesis at global scale. We found that SIF at photosystem (termed as SIFp) is insensitive to solar-viewing geometry and the correlation between SIFp and gross primary production (GPP) is consistent over different biomes.
Correlation between dynamic and static bulk moduli of porous sandstones: Insight from the roles of microcracks and pores

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We studied the continuous evolution of static and dynamic bulk moduli of a porous sandstone (Bentheim sandstone) with isotropic stress under different hydromechanical conditions. The static bulk moduli were achieved from the analysis of the stress-volumetric strain curve while dynamic bulk moduli were derived from the changes in ultrasonic P- and S-wave velocities along different traces which were monitored simultaneously during the entire loading and unloading cycle. To elucidate the effects of microcracks and pores on these moduli, a novel approach, capable of quantitatively determining the evolution of microcrack porosity and pore porosity with pressure in double porous media, was proposed based on poroelastic theory, and such a technique was verified to be practical and reasonable. These moduli were increased drastically with isotropic stress until the crack closure pressure, followed by the stable growth reflecting both dynamic and static bulk moduli are magnificently sensitive to the crack porosity in comparison with pore porosity. We observed the rapid decrease in the magnitude of the dynamic-static modulus ratio prior to the crack closure pressure, and subsequently it tended to level off in the range spanning from 1.0 to 1.15 for dynamic-tangent bulk modulus ratio under dry and undrained conditions. It was estimated that the effect of microcrack porosity on dynamic and static bulk moduli of Bentheim sandstone is approximately an order of magnitude greater than pore porosity regardless in the dry or undrained case. We found there exist two evidently different slopes in the dynamic-static bulk moduli curves separated by the events of microcrack closure suggesting the different roles of microcracks and pores. The distributed cracks in porous sandstone appeared to impose a stronger effect on static bulk moduli than dynamic ones resulting in the gradually narrowed gap between them.
Tin at plate margins – Coupling of tectonic and geochemical processes

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3.1 - Inorganic and Isotope Geochemistry

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Tin mineralization is the result of the superposition of exogenic and endogenic processes connecting tectonic, geochemical, metamorphic, and magmatic aspects. Within the sequence of processes that eventually may lead to Sn mineralization, melting and melt extraction are two critical steps. Melting temperature controls the stability of Sn bearing protolith minerals and, thus, the distribution of Sn between different phases and the mobilization of Sn into the melt. Melt production and timing of melt extractions eventually control the level of Sn enrichment in the melt. Commonly, research on Sn mineralization focuses on late stage magmatic and hydrothermal processes that lead to the formation of an ore body. However, this is just the final step in a sequence of processes. The potential of a specific melt batch to develop mineralization is determined during preceding stages, in particular the mobilization of Sn during partial melting of the Sn source. The key factors seem to be protolith chemistry, melting temperature, and multiple melt extractions, all of which can be linked to specific tectonic settings. The most fertile protoliths are sedimentary rocks that have experienced intense chemical weathering as the composition of the sedimentary rock defines the mineralogy during prograde metamorphism and eventually partial melting. Intense weathering is bound to exposed stable cratonic areas. During breakup of the continent, altered sediments are redistributed to the continent margin and stacked at plate margins. Deeply weathered sediments have elevated concentrations of K and Al and low concentrations of Na and Ca which leads to high modal amounts of muscovite and biotite during metamorphism. These two phases are significant Sn hosts. Furthermore, they control melt production during dehydration melting. While muscovite dehydration melting takes place around 700 °C, biotite dehydration melting requires temperatures in excess of 800 °C. A significant amount of Sn, which is released during the low temperature melting reaction of muscovite, will be redistributed into restitic biotite. In contrast, biotite melting may lead to Sn partitioning into the melt, provided no other Sn sequestering phase is stable. If low temperature melt has not been extracted from the system, overall Sn concentration during biotite-dehydration melting may be elevated, but will never be high as the high Sn content is diluted by the early formed low-Sn melt. In contrast, melt extraction(s) before the breakdown of Sn hosts may lead to significant Sn concentration in late, high temperature melts. As Sn mobilization requires temperatures distinctly above those achieved by internal heating after crustal thickening, Sn mineralization is restricted to tectonic settings with direct or indirect advective heat input from the mantle. Resulting high-temperature, high-Sn melts provide an ideal starting point for additional enrichment by fractional crystallization and/or hydrothermal processes to reach mineralization grade Sn concentrations.
A new sediment core from Lake Lago Grande di Monticchio extending back to ca. 29,000 BP: preliminary results

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5.2 - Climate Dynamics and Landscape Evolution

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The high-resolution Monticchio (MON) sediment record has been demonstrated to be a key archive for reconstructing climate and environmental changes in the central Mediterranean for the last glacial-interglacial cycle (e.g., Allen et al., 1999; Brauer et al., 2007; Martin Puertas et al., 2014). New sediment cores have been retrieved in April 2016 to investigate particularly the transition from the Last Glacial Maximum into the Holocene with a new high-resolution methodological approach. Accordingly, 5 new parallel sediment cores were obtained forming a 12.5 m composite profile covering the last ca. 29,000 yrs. The preliminary age-depth model of the new sediment profile is based on tephrochronology and implements 7 published dates of well-known Italian tephras. These include ages of the Mercato (TM-6b; 8,530±100 cal yrs BP), Verdoline (TM-12; 19,226±104 cal yrs BP) and Pomici di Base (TM-13; 22,081±173 cal yrs BP) eruptions of Vesuvius, as well as the Soccavo (11,700±150 cal yrs BP), Pomici Principali (TM-7b; 12,037±122 cal yrs BP), Neapolitan Yellow Tuff (TM-8; 14,194±172 cal yrs BP) and Y-3 eruptions (TM-15; 29,059±178 cal yrs BP) of the Phlegraean Fields. Additional radiocarbon dating and varve counting on the new cores is currently in progress for establishing a more detailed chronology. Here we present first high-resolution µ-XRF element scanner data combined with new micro-facies data covering the interval between the Pomici di Base (22081±173 cal yrs BP) and Mercato (8530±100 cal yrs BP) tephra layers. Tephra layers and reworked volcanic ash are well reflected by peaks in potassium. Detrital sediments indicated by Titanium (Ti) gradually decrease from the Last Glacial Maximum until the late glacial interstadial with relatively low values and only minor fluctuations. The Younger Dryas is reflected by recurrence of detrital sediments without reaching pleniglacial values. Si/Ti ratios indicate relative variations of diatom productivity in the lake and show only a weak increase during the late glacial interstadial and subsequent decline during the Younger Dryas before the main increase in the early Holocene. Further work including biomarker stable isotopes will particularly focus on the Younger Dryas climate change and the comparison of MON data with high-resolution lake records in western and central Europe.

An improved strain-rate and velocity-dependent seismicity model for subduction zones

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2.6 Seismic Hazard and Risk Dynamics

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The creation of testable global seismic hazard maps implies the construction of seismicity models based on geodetic strain rates, earthquake data and plate-boundary schemes that provide homogeneous global coverage. The SHIFT_GSRM model of Bird and Liu (2007) was designed to provide global high-resolution seismicity forecast models to be used in global hazard assessment. This approach uses the Global Strain Rate Map of Kreemer et al. (2014) to quantify earthquake rates around the globe without the need to map every seismic source. Although SHIFT_GSRM properly estimates rates of shallow seismicity in active continental regions, it underestimates rates of earthquake production in subduction zones by a factor of approximately 3. The model authors explain that such underestimations may stem from the use of inappropriate geometric factors and a velocity-dependence of subduction seismicity.

In this study, we improve SHIFT_GSRM computations for 34 subduction zones by using regional interface earthquake parameters such as seismogenic thickness, subduction dip angle and corner magnitudes. Moreover, we propose an empirical method to constrain time-dependent seismic coupling coefficients that permits us to express rates of seismic moment release both in terms of subduction velocities and geodetic strain rates. Additionally, we also include an analytical term which accounts for the effect of fault dipping in our moment-rate balance equation. By applying this method, we reduce the ratios between observed and SHIFT_GSRM predicted seismicity to an average factor of 1.4. We conclude that this improvement may have a positive impact on the Global Earthquake Activity Rate (GEAR1) seismicity model towards the understanding and development of a testable global seismic hazard model.