SWISS SED Meeting

Twenty-eighth Meeting of Swiss Sedimentologists

Saturday, 11 June 2022

Fribourg

Programme and Abstracts

CUSO CONFÉRENCE UNIVERSITAIF DE SUISSE OCCIDENTALE
UNIVERSITÉ DE GENÈVE FACULTÉ DES SCIENCES Section des sciences de la Terre
UNI FR UNIVERSITÉ DE FRIBOURG UNIVERSITÄT FREIBURG
UNIL | Université de Lausanne
unine UNIVERSITÉ DE NEUCHÂTEL
u^b UNIVERSITÄT BERN
Universität Basel

27th SwissSed Meeting 2019

SwissSed is an informal group of (not only) Swiss sedimentologists. It promotes contacts, exchange of ideas, and information on current developments in sedimentology. Membership is free, but SwissSed lives by the interest and initiative of its members.

To become a member, please contact:

Prof. Flavio Anselmetti
Institute of Geological Sciences
University of Bern
Baltzerstrasse 1+3
3012 Bern
Switzerland
Tel.: +41 31/ 631 87 06
E-mail: flavio.anselmetti@geo.unibe.ch

Prof. Anneleen Foubert
Department of Geosciences – Geology
University of Fribourg
Chemin du Musée 6
1700 Fribourg
Switzerland
Tel.: +41 26/ 300 89 78
E-mail: anneleen.foubert@unifr.ch

Prof. Vincenzo Picotti
ETH Zurich
Geological Institute, NO E 51.2
Sonneggstrasse 5
8092 Zürich
Switzerland
Tel.: +41 44/ 632 81 60
Email: vincenzo.picotti@erdw.ethz.ch

Prof. Elias Samankassou
Department of Earth Sciences
University of Geneva
Rue des Maraichers 13
1205 Genève
Switzerland
Tel.: +41 22/ 379 66 20
E-mail: elias.samankassou@unige.ch

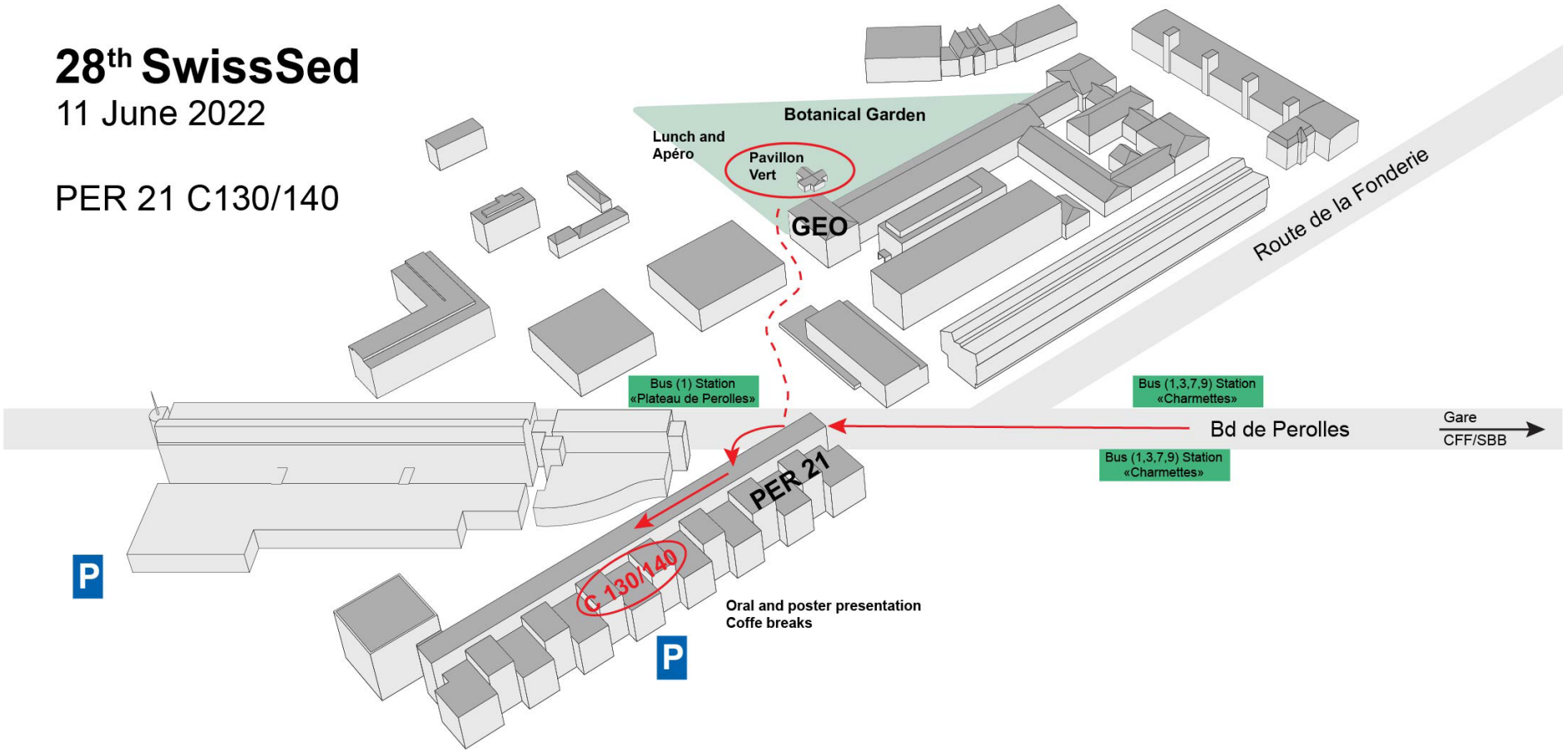
Dr. Silvia Spezzaferri
Department of Geosciences – Geology
University of Fribourg
Chemin du Musée 4
1700 Fribourg
Switzerland
Tel.: +41 26/ 300 89 77
E-mail: silvia.spezzaferri@unifr.ch

SwissSed on the Web:
New website is under construction

28th SwissSed

11 June 2022

PER 21 C130/140



PROGRAMME

09.00 - 09.30 Morning coffee and croissant

09:30 - 09:40 Opening

09:40 - 09:55 **Tribute to Karl Föllmi**
Thierry Adatte, Stéphane Bodin, Brahimsamba Bomou, Fantasia Alicia, Alexis Godet, Bas Van de Schootbrugge

09:55 - 10:40 **Keynote: Shallow-marine carbonates as recorders of orbitally induced past climate changes**
André Strasser

10:40 – 11:00 **1-slide Poster Pitch presentations:**

Determining the age and tectonic evolution of the oceanic crust using calcite U-Pb geochronology and biostratigraphy
Goran Andjić, Renjie Zhou, David M. Buchs, Jonathan Aitchison, and Jianxin Zhao

Stratigraphy, rocks and fossils of the Gemmi-Lämmerenalp area (VS), a poster for teaching and outreach
Peter O. Baumgartner, Jean-Luc Epard, Claudia Baumgartner-Mora and Stefan M. Schmalholz

Radiocarbon geochemistry of amino acids in marine sediments
Thomas Blattmann

Ecological dynamics of coralgal reef terraces during MIS 7 Danakil Basin (Northern Afar, Ethiopia)
Addis Endeshaw, Haileyesus Negga, Nadia Santodomingo, Valentin Rime, Xenia Haberditz, Balemwal Atnafu, Juan Carlos Braga, David Jaramillo-Vogel, Tesfaye Kidane, and Anneleen Foubert

Provenance of the arenites in the Alpine foreland basin at the time of the Wildflysch based on an integrated geo-thermochronological approach
Florence Emanuelle Frund, Maria Giuditta Fellin, Vincenzo Picotti, and Sean D. Willett

11:00 - 11:30 Coffee break and poster session

11:30 - 11:50 **Formation and Middle Triassic dissolution of Middle Muschelkalk halite deposits in Northern Switzerland**
Johannes Pietsch, Andreas Wetzel, Gaudenz Deplazes, and Marco Filipponi

11:50 - 12:10 **Harmonisation of Opalinus Clay descriptions in Northern Switzerland: towards a uniform Subfacies Classification Scheme**
Géraldine Zimmerli, Bruno Lauper, Gaudenz Deplazes, David Jaeggi, Stephan Wohlwend, and Anneleen Foubert

12:10 - 12:30 **Early Triassic Wildfire Increase in Northern High Latitudes**
Franziska R. Blattmann, Zoneibe A. S. Luz, Torsten Vennemann, Thierry Adatte, Hugo Bucher, and Clayton R. Magill

12:30 - 14:00 Lunch and group picture at Pavillon Vert

14:00 - 14:20 **Nano-scale pathways of modern dolomite formation in Lake Neusiedl, Austria: insights from high-resolution transmission electron microscopy**
Patrick Meister, Silvia Frisia, Péter Pekker, Zsombor Molnár, Stephanie Neuhuber, Susanne Gier, Attila Demény, and Mihály Pósfai

14:20 - 14:40 **The Late Holocene (Meghalayan) mega-drought Impact on the late Medieval Egypt: Geochemical and Palynological proxies from Inland Saline Lake Sediments at Wadi El-Natrun (Western Nile Delta, Egypt)**
Amr S. Zaky, Hendrik Vogel, and Flavio Anselmetti

14:40 - 15:00 **A percentile-based comparison of three individual measuring techniques of coarse-grained fluvial deposits from vertical outcrops**
Philippos Garefalakis, Ariel Do Prado, David Mair, Franziska Nyffeneger, and Fritz Schlunegger

15:00 - 15:20 **Determining the controls on flow behaviour, bedform development and stratigraphic architecture from detailed surveys and monitoring of active submarine channels**
Daniela Vendettuoli

15:20 – 15:30 **Insights into the Formation of Southeastern Mediterranean Seep Carbonates**
Reinhard Weidlich, Or Bialik, Andres Rüggeberg, Bernard Grobéty, Thorsten Vennemann, Yizhaq Makovsky, and Anneleen Foubert

15:30 - 16:00 ***Coffee break and poster session***

16:00 - 16:20 **Taxonomy of Pleistocene reef coral family Merulinidae (Cnidaria: Scleractinia) from the Danakil Depression, Ethiopia**
Addis Hailu Endeshaw, Nadia Santodomingo, and Anneleen Foubert

16:20 - 16:40 **From sea to a saline desert: the story of the late Pleistocene to Holocene desiccation of the Danakil Depression, Afar, Ethiopia**
Valentin Rime, Anneleen Foubert, Robin Fentimen, Afifé El Korh, Haileyesus Negga, Claudius Pinkenseer, Irka Hajdas, Thierry Adatte, Balemwal Atnafu, and Tesfaye Kidane

16:40 – 17:00 **Bajocian coral reefs of the "Herrenwis Unit" in North- Eastern Switzerland**
Arnaud Ruchat, Bernard Lathuilière, Stephan Wohlwend, Gaudenz Deplazes, Herfried Madritsch, Gregor P. Eberli, Ovie E. Eruteya, and Elias Samankassou

17:00 Closure

Apéro at Pavillon Vert (Botanical Garden)

POSTERS

Goran Andjić, Renjie Zhou, David M. Buchs, Jonathan Aitchison, and Jianxin Zhao: Determining the age and tectonic evolution of the oceanic crust using calcite U-Pb geochronology and biostratigraphy

Peter O. Baumgartner, Jean-Luc Epard, Claudia Baumgartner-Mora and Stefan, M. Schmalholz: Stratigraphy, rocks and fossils of the Gemmi-Lämmerenalp area (VS), a poster for teaching and outreach

Thomas Blattmann: Radiocarbon geochemistry of amino acids in marine sediments

Addis Endeshaw, Haileyesus Negga, Nadia Santodomingo, Valentin Rime, Xenia Haberditz, Balemwal Atnafu, Juan-Carlos Braga, David Jaramillo-Vogel, Tesfaye Kidane, Anneleen Foubert: Ecological dynamics of coralgal reef terraces during MIS 7 Danakil Basin (Northern Afar, Ethiopia)

Florence Emanuelle Frund, Maria Giuditta Fellin, Vincenzo Picotti, Sean D. Willett: Provenance of the arenites in the Alpine foreland basin at the time of the Wildflysch based on an integrated geo-thermochronological approach

SwissSed Meeting 2022 – (Pre)registered participants

Adatte, Thierry	Lausanne
Andjic, Goran	Lausanne
Anselmetti Flavio	Bern
Baumgartner, Peter O.	Lausanne
Bläsi, Hansruedi	Bern
Blattmann, Franziska	Lausanne
Blattmann, Thomas	Zurich
Bollen, Michael	Lausanne
Carraro, Davide	Geneva
Culiat, Nevia	Fribourg
Deplazes, Gaudenz	Wettingen
Edward, Oluwadeun	Lausanne
Endeshaw, Addis Hailu	Fribourg
Foubert, Anneleen	Fribourg
Francescangeli, Fabio	Fribourg
Frund, Florence	Bern
Garefalakis, Philippos	Bern
Gebru, Ermias	Fribourg
Harlet, Deborah	Bern
Jamart, Valentin	Lausanne
Karabeyoglu, Uygar	Lausanne
Mangiagalli, Matteo	Fribourg
Martini, Rossana	Geneva
Matter, Albert	Bern
Meister, Patrick	Vienna
Morard, Alain	Swisstopo
Negga, Haileyesus	Fribourg
Picotti, Vincenzo	Zurich
Pietsch, Johannes	Basel
Rime, Valentin	Fribourg
Ruchat, Arnaud	Geneva
Rüggeberg, Andres	Fribourg
Santodomingo, Nadia	London
Schuster, Bennet	Bern
Strasser, André	Fribourg
Sturny, Janine	Fribourg
Vendettuoli, Daniela	Bern
Vincent, James	Geneva
Zaky, Amr	Bern
Zimmerli, Geraldine	Fribourg

Tribute to Prof. Dr. Karl Föllmi

Continent-ocean interactions and their sedimentological records: the Legacy of Karl Föllmi

Thierry Adatte[1*], Stéphane Bodin[2], Brahimsamba Bomou[1], Fantasia Alicia[2], Alexis Godet[3], Bas Van de Schootbrugge[4]

[1)] *ISTE, University of Lausanne, Lausanne, Switzerland*
[2)] *Department of Geoscience, Aarhus University, Aarhus, Denmark*
[3)] *Department of Geological Sciences, University of Texas, San Antonio, United States of America*
[4)] *Institute of Marine palynology and palaeoceanography, University of Utrecht, Utrecht, Netherlands*

* *Email address of corresponding author: thierry.adatte@unil.ch*

Although is not easy to sum up the scientific career of Karl Föllmi, who died on 30 September of last year, we aim to share his thought that sedimentology and stratigraphy was a dynamic science tremendously important to understand our past, present and future Earth. Continent-ocean interactions and their records, in particular in Mesozoic shallow-water carbonates, were one of the favourite research topics of Karl Föllmi.

Föllmi's research was based on a multiproxy approach with a special focus on the phosphorous cycle that he was considering as a crucial element to understand shallow carbonate platforms development. His investigations of early Cretaceous sediments from the Helvetic domain allowed him to build a model explaining the rise and demise of the reefs and carbonate platforms during this greenhouse period of the Earth's history. Using a modern and holistic approach including sophisticated analytical tools, Karl was one of the first sedimentologist to show that fossil reef and platform systems were vital and interactive compartments of the Earth and its biosphere.

Karl demonstrated convincingly that, in spite of many differences between Early Cretaceous and present-day time periods (e.g. the palaeogeography, oceanic circulation pattern and the absence of ice caps), the study of ancient carbonate platforms appeared to be applicable to the present-day world. Early Cretaceous reefs and carbonate platforms in general were very sensitive to environmental change (especially changes in trophic levels, sea level, pH, temperature and influx of freshwater) and, by comparison with other depositional situations, were the first to be destroyed and the last to recover. Karl's approach was strongly motivated by the parallels existing with present-day anthropogenic changes. Increasing phosphorous flux into the oceans, mainly coming from anthropogenic sources is generating eutrophication and oxygen depletion in modern marginal oceanic basins near heavily urbanized areas and consequently leading to a severe degradation of the reefs and carbonate platforms.

Karl's research added and still adds much exciting information to the field of palaeoenvironmental and palaeoceanographic research on platform systems, most acquired through the so-called 'multi-proxy' analysis of rock records that he applied not only to Early Cretaceous series but also to Jurassic and Miocene successions. He was persuaded that this

trend will continue and that new methods and fields will result in new, innovative and holistic interpretations of the ancient environments and climates. As such, many challenges are present in today's research on ancient carbonate platforms and thanks to Karl, there is a bright future for stimulating discoveries.

With the passing of Karl Föllmi, the sedimentology and stratigraphy community lost a scientist of international reputation, a gifted teacher and mentor, and above all a good friend.

Keynote:

Shallow-marine carbonates as recorders of orbitally induced past climate changes

André Strasser

University of Fribourg, Department of Geosciences, Chemin du Musée 6, CH-1700 Fribourg, Switzerland

Email address: andreas.strasser@unifr.ch

In today's world of global climate change and its impact on *Homo sapiens*, research into past climate variability as recorded in sediments becomes particularly interesting. Rapid and profound climate-induced changes in the palaeoecosystems can thus be documented and may serve as examples of changes we may experience in the near future. Here, an example from the Oxfordian (Late Jurassic) of the Swiss Jura Mountains is presented.

The sediments formed on a shallow subtropical platform where carbonate-producing organisms proliferated, and ooids and oncoids were common. The studied sections are composed of hierarchically stacked elementary, small-scale, and medium-scale depositional sequences where facies changes imply deepening-shallowing trends. The major sequence boundaries Ox 6, Ox 7, and Ox 8 can be correlated with those of other European basins and place the sections in a broader framework. The chronostratigraphic tie points imply that the medium- and small-scale sequences formed in tune with the orbital eccentricity cycles of 405 and 100 kyr, respectively, and the elementary sequences with the precession cycle of 20 kyr. Orbitally controlled insolation changes at the top of the atmosphere translated into climate changes: low insolation generally resulted in low sea-level amplitudes at the 20-kyr frequency, and in a cool and humid climate at the palaeolatitude of the Jura platform. Terrigenous material was eroded from the hinterland and distributed over the platform. High insolation led to sea-level rise to create accommodation, and to warm and semiarid to arid conditions in which coral reefs could grow. However, nutrient input favoured growth of microbialites that encrusted the corals. The reconstruction of high-frequency sea-level fluctuations based on facies analysis compares well with the curve of insolation changes calculated for the past 500 kyr. It is therefore assumed that sea-level fluctuations were mainly due to thermal expansion and retraction of ocean surface water.

Two models are presented that explain the formation of elementary sequences, one for low and one for high insolation. Despite the important lateral facies variations typical of a shallow-marine platform, and despite the uncertainties in the reconstruction of sea-level changes, this study demonstrates the potential of carbonate ecosystems to record past climate changes at a time resolution of 20'000 years. Relatively short time-windows can thus be opened in the deep geologic past, and processes and products there can be compared with those of the Holocene and the Recent. For example, it appears that today's anthropogenically induced sea-level rise is more than ten times faster than the fastest rise reconstructed for the Oxfordian.

Abstracts (alphabetical order):

Determining the age and tectonic evolution of the oceanic crust using calcite U-Pb geochronology and biostratigraphy

Goran Andjić[(1)*], Renjie Zhou[(2)], David M. Buchs[(3)], Jonathan Aitchison[(2)], and Jianxin Zhao[(2)]

[1] *Institut des Sciences de la Terre, Université de Lausanne, Bâtiment Géopolis, CH-1015 Lausanne*
[2] *School of Earth and Environmental Sciences, The University of Queensland, 4072 St Lucia, Australia*
[3] *School of Earth and Environmental Sciences, Cardiff University, United Kingdom*

*Email: goran.andjic@unil.ch

Active accretionary wedges result from the convergence between a downgoing oceanic plate and an overriding plate. There, loose sediment and rock material sourced from both plates is stacked into fault-bounded, deformed packages that are incorporated into the overriding plate. In modern settings, both accretionary complexes and downgoing plates lay far below sea level, making methods of getting first-hand observations complex and costly (such as drilling/dredging/seismic reflection). In contrast, exhumed ancient accretionary complexes provide a more accessible way to study the tectonic evolution of subduction zones and oceanic plates partly or completely lost to subduction.

Documenting the history of ancient oceanic plates from accretionary complexes is faced with the challenge of dealing with dismembered pieces of oceanic crust, whereby the original succession of lithologies−called ocean plate stratigraphy (Isozaki et al., 1990)−was partly or entirely lost. Establishing the timing of formation and subduction of oceanic plates hence implies determining the age of meter- to kilometer-sized blocks of oceanic crust and the sedimentary matrix in which they are embedded. Dating ocean plate stratigraphy in accretionary complexes has classically relied on paleontology rather than on geochronology because processing and identifying fossils, such as radiolarians, are well practiced by the community. In contrast, mafic igneous rocks from the oceanic crust generally lack minerals commonly used in geochronological studies (such as zircon), and are often subject to strong alteration. Therefore, if a block of mafic igneous rock is not in stratigraphic contact with a datable sedimentary rock, its age is very likely to remain unknown.

We studied the accretionary complex represented by the Carboniferous Texas Beds in the southern segment of the New England Orogen, which is the youngest belt of a collage of Paleozoic subduction-related orogens occupying the eastern third of the Australian continent. Altered ocean island basalt (OIB)-like rocks, cherts and shallow-marine carbonates are embedded throughout the complex. Although these rock associations were considered to represent remnants of oceanic islands based on existing biostratigraphic, geochemical and lithological data, their original relationship was obscured by tectonic dismemberment, possibly during accretion and/or gravitational collapse of islands arriving at the subduction zone. Their exact timing of formation and accretion, which is critical to reconstruct the origin and evolution of the dismembered ocean plate stratigraphy, was not known before.

Two distinct types of calcite were formed in the studied OIB-like volcanic rocks. One calcite type precipitated in amygdules (voids representing former gas bubbles in a molten lava), whereas the other type precipitated in orthogonal fractures which are also visible among all

the lithologies in the accretionary complex. Besides distinct morphologies, these calcites have distinct U-Pb geochronological ages and geochemical signatures. Calcite precipitation from low-temperature hydrothermal fluids in amygdules occurred at around 378–354 million years ago, whereas calcite precipitation from seawater in fractures occurred at around 331–279 million years ago.

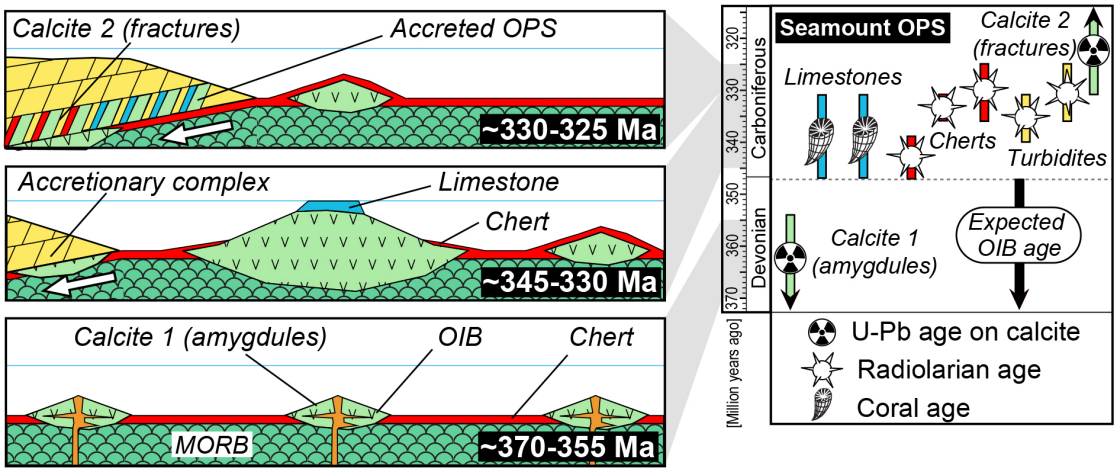


Figure 1. Summary of the age constraints used to establish the timing of formation and accretion of Paleozoic intraplate volcanoes. Modified from Andjić (2022) and Andjić et al. (2022). OPS = Ocean Plate Stratigraphy; OIB = Oceanic Island Basalt; MORB = Mid-Ocean Ridge Basalt.

Taken at face value, the timing of precipitation of the two generations of calcite does not translate into clear geological implications. It is only when combined with new and existing fossil age data that the significance of the geochronological ages becomes meaningful. When integrating data from all the lithologies making up the accretionary complex, it is possible to reconstruct the following sequence of events (Figure 1):

-> no later than 354 million years ago = intraplate volcanic eruptions;
-> 347–330 million years ago = deep to shallow marine sedimentation on intraplate volcanoes;
-> 330–325 million years ago = accretion of intraplate volcanoes to Gondwana;
-> no earlier than 330 million years ago = brittle deformation of intraplate volcanoes within the accretionary complex.

The main conclusion of our work is that a minimum age of formation of altered and weathered, mafic volcanic rocks can be obtained using calcite U-Pb geochronology. In the context of accreted ocean plate stratigraphy, the broader geological implications of the minimum age of formation of volcanic rocks have to be determined in conjunction with fossil, structural, and geochemical data.

References

Andjić, G. (2022). Calcite U-Pb geochronology can provide minimum formation age of ancient oceanic crust. Nature Portfolio Earth and Environment Community. https://go.nature.com/3yrHh8u.

Andjić, G., Zhou, R., Buchs, D.M., Aitchison, J.C., Zhao, J. (2022). Paleozoic ocean plate stratigraphy unraveled by calcite U-Pb dating of basalt and biostratigraphy. Communications Earth & Environment 3: 113. https://doi.org/10.1038/s43247-022-00446-1.

Isozaki, Y., Maruyama, S. & Furuoka, F. (1990). Accreted oceanic materials in Japan. Tectonophysics 181: 179–205. https://doi.org/10.1016/0040-1951(90)90016-2.

Stratigraphy, rocks and fossils of the Gemmi-Lämmerenalp area (VS), a poster for teaching and outreach

Peter O. Baumgartner*, Jean-Luc Epard, Claudia Baumgartner-Mora and Stefan, M. Schmalholz

Université de Lausanne, Institut des Sciences de la Terre, Géopolis, CH-1015 Lausanne, Switzerland

* peter.baumgartner@unil.ch

The Gemmi-Lämmerenalp area gives easy access to excellent outcrops of a mildly deformed Upper Jurassic-Lower Cretaceous and Paleogene sedimentary sequence of the North-Helvetic Doldenhorn nappe. Traditionally, field camps are organized by the ETH and the University of Lausanne to train students in geological mapping, stratigraphical and structural observation. Also, numerous hikers frequent the area, potentially interested in knowing more about the geology. However, to our knowledge, no recent account on the stratigraphy, sedimentology and fossils of the area has been published, that would be easily accessible to students and an interested public.

Furrer (1962) briefly described the lithologic units of the Doldenhorn nappe in the explanatory booklet to the Gemmi geological map (Atlas sheet 1267). Herb in Masson et al. (1980, p. 142) gave an excellent description of the Jurassic to Eocene section of the Doldenhorn nappe in the area. More recently, Gansner (2000) presented a diploma work supervised by H. Funk and H. Weissert on the stratigraphy and sediment petrology of the sections indicated by Herb. Bonvallet et al. (2020) presented a highly fluctuating carbon isotope record of the Tierwis and Schattenkalk formations at Lämmerenplatten, that does not correlate with records from other Helvetic sections. According to the authors, it is affected by low grade metamorphism.

Here, we present a first working version of a poster that includes a revised stratigraphic column with a chronostratigraphic correlation of the Mesozoic part to the northern Helvetic realm in the space -time diagram by Föllmi (2007, fig. 2). A set of commented panoramas and outcrop images is provided for each formation, showing formational boundaries and typical facies and fossils. Typical fossil groups of each formation are illustrated for teaching purposes, with images from the area, but also with illustrations of well-preserved micro- and macrofossils from elsewhere, including the literature.

While Föllmi's chronology is calibrated by many published fossil occurrences (ammonites, calpionelids etc.) in central and eastern Switzerland, these ages are at present poorly confirmed by fossils in the Gemmi area. A general, lithostratigraphic correlation of the Lämmeren section with Helvetic sections in central and eastern Switzerland seems feasible at the level of formations. In particular, the main disconformities in the Berriasian-Barremian interval can be correlated well. However, the corelation of members is problematic and calls for a refined sedimentologic and sequence-stratigraphic analysis of the Gemmi area, as well as the definition of new members.

The lower part of the Quinten Formation is characterized by dm- to m-bedded light grey micritic limestones alternating with several thinner-bedded marly limestone intervals. Besides a supposed pelagic component, much of the micrite should represent peri-platform ooze. Belemnites are frequent in some beds. A more important marly limestone interval could represent the "Mergelband" recorded in other Helvetic sections. The upper part of the Quinten Formation, here informally termed "Lämmerendalu member" is characterized by

several intervals of 3-10 cm-bedded alternating light and dark grey, nodular dolomitic limestones and limestone breccias. Gansner (2000) reported sparse bioclasts, such as aptychy, *Saccocoma* and calcified sponge spicules, that must have resulted in the diagenetic formation of occasional chert nodules. We observed patches of encrusting corals and echinid spines, that could represent an offshore, lower photic zone paleo-environment. This new member clearly differs from the shallow platform Troos Member of central Switzerland.

The Zementstein Formation appears as soft slopes of thin-bedded, dank grey argillaceous limestones with marl joints. Some interbedded limestone beds can be followed over a few km. A set of several 3-4 dm thick limestone beds (equivalent of the Graspass Member?) mark the passage to the Öhrli Formation. It consists of at least 5 cycles, composed of a basal, thin-bedded marly limestone interval and thick-bedded white limestone top. These cycles are contiguous from Lämmerenboden to Rote Chumme but show important thickness variations that cannot be attributed to tectonics. Marly intervals may contain large slump masses indicated by rotated bedding. We need further observations to determine, if the thick-bedded tops correspond to platform growth.

The contact with the condensed Betlis Formation is sharp, shows sedimentary dykes filled with echinoderm-quartz sands. The top of the Betlis Formation is a paleo-karst infilled with echinoderm-rich sands (equivalent of *Pygurus* Beds?). The Helvetic Kieselkalk Formation is well developed with characteristic colour changes to be analysed. Its top is marked by a sharp contact with the grey Tierwis Formation (equivalent of the Altmann Member?).

Only a maximum of 20 m of the lower Schrattenkalk is preserved beneath the unconformity onlapped by the upper Eocene quartzose sandstones and lithothamnid limestones. We here include these beds with the Sanetsch Formation (Menkveld-Gfeller,1994), based on lithologic similarities with the Diablerets and the Tsanfleuron Members of this formation. Preliminary examination of outcrops and thin sections revealed small nummulites resembling the Priabonian *Nummulites retiatus* Roveda, 1959, already mentioned by Herb (1988, p.635) in the Priabonian of the Doldenhorn nappe of the Kiental. Herb in Masson et al. (1980) mentions a level with *Cerithium* in the lower part of the Eocene beds at Rote Chumme. Thus, we favour the working hypothesis that only the lower members of the Sanetsch Formation are preserved beneath the overthrust of the Gellihorn nappe, between Lämmerensee and Rote Chumme. The Siderolithic Group is present in the underlying formations in paleo-karst pockets, which may present an internal stratigraphy (including *Microcodium*) to be investigated.

References

Bonvallet, L., Arnaud-Vanneau, A., Arnaud, H., Adatte, T., Spangenberg, J. E., Stein, M., Godet, A., Föllmi, K. B. (2019) Evolution of the Urgonian shallow-water carbonate platform on the Helvetic shelf during the late Early Cretaceous. Sedimentary Geology 387, 18–56.

Föllmi, K.B., Bodin, S., Godet, A., Linder, P., van de Schootbrugge, B. (2007) Unlocking paleoenvironmental information from Early Cretaceous shelf sediments in the Helvetic Alps: stratigraphy is the key! Swiss Journal of Geosciences 100, 349–369.

Furrer, H. (1962) Erläuterungen zum geologischen Atlas der Schweiz, Blatt: Gemmi, 1 :25'000. Schweizerische geologische Kommission.

Gansner, C. (2000) Geologische Untersuchungen im Gebiet Gemmipass-Lömmerenboden-LämmerenalpäKummen, Leukerbad Kanton Wallis. Diplomarbeit, Geologisches Institut ETH.

Herb, R. (1988) Eozäne Paläogeographie und Paläotektonik des Helvetikums. Eclogae geol. Helv. 81/3, 611-657.

Masson, H., Herb, R., Steck, A. (1980) Helvetic Alps of Western Switzerland. In: (Ed) R. Trümpy, Geology of Switzerland. part B. Basel. Wepf & Co. 109-135.

Menkveld-Gfeller, U. (1994) Die Wildstrubel-, die Hohgant- und die Sanetsch-Formation: Drei neue lithostratigraphische Einheiten des Eocaens der helvetischen Decken. *Eclogae Geol. Helv.*, 87: 789–809.

Taxonomy of Pleistocene reef coral family Merulinidae (Cnidaria: Scleractinia) from the Danakil Depression, Ethiopia

Addis Hailu Endeshaw*[(1)], Nadia Santodomingo[(2)] and Anneleen Foubert[(1)]

[(1)] *University of Fribourg, Department of Geosciences, Chemin du Musée, CH-1700 Fribourg, Switzerland*
[(2)] *Natural History Museum of London, Cromwell Road SW7 5BD, London, United Kingdom*

*Email: Endeshaw.Addis@unifr.ch

Coral reefs are the most diverse marine ecosystems in the world. They are mainly built by Scleractinian corals, which hard skeletons give the opportunity to provide an excellent fossil record. The taxonomic composition of reef building organisms in the fossil record is used as a proxy to better understand environmental changes in the past. The Danakil Depression is in the northern Afar characterized by the occurrence of fringing coralgal reefs at its western, central and eastern margins. These coralgal reef terraces developed respectively at MIS 7 and MIS 5e when the Red Sea flooded the Danakil Depression (*Foubert et al., 2015; Jaramillo-Vogel et al., 2018*).

This study focuses on the taxonomic descriptions and identifications of the Scleractinian coral family Merulinidae from samples collected during the SNF-funded SERENA project (SEdimentary REcord of Northern Afar). Surveys were done in January – February (2013, 2015, 2017, 2019 and 2020) with the aim to understand the taxonomy and paleoecology of the coralgal reef terraces. In total, 578 coral samples were collected from 32 coral outcrops and 350 specimens were examined in this study.

Samples were cleaned for detailed morphological analysis. Preservation conditions of the fossil specimens were considered to avoid biases in the taxonomic identification. Quantitative and qualitative morphological characters were studied on the specimens or thin sections using standard microscopy techniques and X-ray micro-tomographic scanning (Bruker 2211).

This study follows the macromorphological characters described by *Best (1972, 1974, 1980)*, *Veron & Pichon (1980),* and *Veron et al. (1977)*; the micromorphological and microstructural characters as described following *Budd & Stolarski (2009, 2011)*, *Budd et al. (2012)* and *Huang et al. (2014)*. The taxonomic status of the identified species follows the classification and nomenclature in WoRMS - World Register of Marine Species (2022). With this approach, results will contribute to the current Scleractinia phylogenetics framework which integrates molecular, micromorphological and microstructural characters (*Fukami et al., 2008*; *Arrigoni et al., 2012*; *Budd et al., 2012* & *Huang et al., 2014*).

The Merulinidae fauna of the Danakil Depression comprises 16 genera: *Astrea, Caulastraea, Coelastrea, Cyphastrea, Dipsastraea, Echinopora, Favites, Goniastrea, Leptoria, Merulina, Mycedium, Oulophyllia, Paragoniastraea, Paramontastraea* and *Platygyra* with 68 species. All these species are the first records for Pleistocene coralgal reef terraces of the Danakil Depression. Results evidence new records of *Caulastraea tumida*, *Caulastraea furcata*, *Cyphastrea hexasepta, Cyphastrea chalcidicum, Dipsastraea helianthoides*, *Dipsastraea veroni, Goniastrea columella, Merulina scabricula, Mycedium umbra, Oulophyllia crispa, Oulophyllia levis, Paragoniastraea australensis, Paramontastraea salebrosa,* and *Platygyra contorta* for the Pleistocene Red Sea Scleractinian species.

References

Arrigoni, R., Benzoni, F., Stefani, F., Pichon, M. & Galli, P. (2012). Molecular phylogeny of the Robust Clade (Faviidae, Mussidae and Pectiniidae): An Indian Ocean perspective. *Molecular Phylogenetics and Evolution*. **65**: 183-193.

Atnafu, B., Kidane, T., Foubert, A., Jaramillo-Vogel, D., Schaegis, J-C., and Henriet, J-P (2015) Reading history from Afar. EOS, *Earth and Space Science News*, **96**: 1-2.

Budd, A.F. & Stolarski, J. (2009). Searching for new morphological characters in the systematics of scleractinian reef corals: comparison of septal teeth and granules between Atlantic and Pacific Mussidae. *Acta Zoologica.* **90**: 142 – 165.

Budd, A.F. & Stolarski, J. (2011). Corallite Wall and Septal Microstructure in Scleractinia Reef Corals: Comparison of Molecular Clades within the Family Faviidae. *Journal of Morphology.* **272**: 66–88.

Budd, A.F., Fukami, H., Smith, N.D. & Knowlton N. (2012). Taxonomic classification of the reef coral family Mussidae (Cnidaria: Anthozoa: Scleractinia) *Zool. J. Linn. Soc.,* **166**: 465-529.

Foubert, A., Jaramillo-Vogel, D., Eisenhauer, A., Schaegis, J-C., Atnafu, B., and Kidane, T. (2015) Coral reefs and microbial deposits in an active rift setting: insight from the Danakil Depression (Afar, Ethiopia). In: Proceedings of the 15th Bathurst Meeting, pp. 53-54.

Fukami, H., Chen, C.A., Budd, A.F., Collins, Wallace, C., Chuang, Y.Y., Chen, Dai, C.F., Iwao, K., Sheppard, C. & Knowlton, N. (2008). Mitochondrial and nuclear genes suggest that stony corals are monophyletic but most families of stony corals are not (order Scleractinia, class Anthozoa, phylum Cnidaria). *PLoS ONE*. **3**: e3222

Hoeksema, B. W. & Cairns, S. (2022). World List of Scleractinia. Merulinidae Milne Edwards & Haime, 1857. Accessed through: World Register of Marine Species at: https://www.marinespecies.org/aphia.php?p=taxdetails&id=1579843

Huang, D., Benzoni, F., Fukami, H., Knowlton, N., Smith, N.D. & Budd, A.F. (2014). Taxonomic classification of the reef coral families Merulinidae, Montastraeidae, and Diploastraeidae (Cnidaria: Anthozoa: Scleractinia). *Zool. J. Linn. Soc.*, **171**: 277–355.

Jaramillo-Vogel, D., Foubert, A., Braga J. C., Schaegis, J-C., Atnafu, B., Grobety B., and Kidane, T. (2018) Pleistocene sea-floor fibrous crusts and spherulites in the Danakil Depression (Afar, Ethiopia). Journal of International Sedimentology, odi: 10.1111/sed.12484.

Veron, J.E.N. & Pichon, M. (1980). Scleractinia of Eastern Australia. Part III. Families Agaraciidae, Siderastreidae, Fungiidae, Oculinidae, Merulinidae, Mussidae, Pectiniidae, Caryophylliidae, Dendrophylliidae. Australian Institute of Marine Science. *Monograph Series.* **4**: 1 – 471.

Veron, J.E.N., Pichom M., & Wijsman-Best M. (1977). Scleractinia of Eatsrn Australia. Part II. Families Faviidae, Trachyphylliidae. Australian Institute of Marine Science. *Monograph Series.* **3**: 1 – 233.

Wijsman-Best, M. (1972). Systematics and Ecology of New Caledonian Faviinae (Coelenterata - Sclearctinia). Institute of Taxonomic Zoology, University of Amsterdam, The Netherlands. **42 (1)**: 1 – 90.

Wijsman-Best, M. (1974). Biological Results of the SNELLIUS Expedition XXV Faviidae Collected by the SNELLIUS Expedition I. The Genus Favia. Zoologische Mededelingen. BIJDRAGEN TOT DE DIERKUNDE **48**(22): 249 – 265.

Wijsman-Best, M. (1980). Indo-Pacific coral species belonging to the subfamily Montastreinae Vaughan & Wells, 1943 (Scleractinea- Coelenterata) Part II. The genera Cyphastrea, Leptastrea, Echinopora and Diploastrea. Zoologische Mededelingen, **55**, 235–263.

Provenance of the arenites in the Alpine foreland basin at the time of the Wildflysch based on an integrated geo-thermochronological approach

Florence Emanuelle Frund*(1), Maria Giuditta Fellin(2), Vincenzo Picotti(2), Sean D. Willett(2)

(1) *University of Bern, Institute of Geological Science, Baltzerstrasse 1+3, CH-3012 Bern, Switzerland*
(2) *ETH Zurich, Earth Sciences Department, Sonneggstrasse 5, CH-8092 Zürich*

* Email address of corresponding author: florence.frund@geo.unibe.ch

The Wildflysch is exposed in central Switzerland and was first described by Kaufman (1886). It consists of alternating turbiditic sandstones and disrupted beds that include olistotliths of Habkern Granite and Triassic (with European affinity) to Cretaceous-Paleogene sedimentary rocks. It was deposited in the Priabonian to ?Rupelian, on top of and/or interfingering with marls rich in globigerinids (Stad Formation), which are also Priabonian in age (Menkveld-Gfeller et al., 2016). These marls, in turn, overlie near-shore, nummulite-rich, quartz-sandstones (Niederhorn Formation) that were deposited on the European margin and that encroached northward in response to the flexural loading due to the growing alpine wedge (Allen et al., 1991). This stratigraphic succession is exposed both near Habkern and in the Suld Valley, which are to the north and to the south of Lake Thun, respectively.
Double dating of detrital zircons from the Wildflysch and the Habkern Granite exposed near Habkern and from the Stad Formation in Suld reveal different U-Pb signatures and no alpine overprint of the zircon fission-track system. The Habkern Granite, from the geologic collection of the museum of the Department of Earth Sciences of ETH Zurich, features a Late Carboniferous (~300-315 Ma) U-Pb age population with no older ages and a main zircon fission-track populations centered in the Late Jurassic. A glauconite-rich turbiditic sandstones collected near Habkern, carrying grains of Habkern Granite, features a major Late Carboniferous U-Pb population similarly to the Habkern Granite, and minor older populations that date back to the Early Carboniferous (~340 Ma), the Cambrian (~500 Ma) and the Neoproterozoic (~620 Ma). The main zircon fission-track population in this sample is Early-Middle Jurassic in age. Near Suld, a sandstone bed within marly layers (Stad Formation), a few meters higher than a massive quartzarenite unit (Niederhorn Formation), have U-Pb ages that form a large Early Carboniferous population (~330-340 Ma) and minor Cambrian and older populations. Zircon fission-track ages in this sample are mostly Mid-Jurassic or older. Based on the composition of the sampled layers, on their U-Pb signatures and on previous stratigraphic data, we postulate that the Wildflysch and Stad Formation represent different facies of the Alpine foreland basin with distinct provenance. The Stad Formation was deposited on the foreland ramp and was occasionally fed by material reworked from the shelf of the European margin, whereas the Wildflysch was deposited in the foredeep and was fed mostly by material coming from the Alpine wedge, including olistoliths of the Habkern granite and other rocks, and possibly locally mixing with material from the foreland ramp.

References:

Allen, P. A., Crampton, S. L., and Sinclair, H. D., 1991, The inception and early evolution of the North Alpine Foreland Basin, Switzerland: *Basin Research*, v. 3, p. 143–163.

Kaufmann, F.J., 1886, Emmen- und Schlierengegenden nebst Umgebungen bis zur Brünigstrasse und Linie Lungern-Grafenort: Beiträge zur Geologische Karte der Schweiz, v. 24, no. 1, 608 p.

Menkveld-Gfeller, U., Kempf, O., & Funk, H. (2016). Lithostratigraphic units of the Helvetic Palaeogene: Review, new definition, new classification. *Swiss Journal of Geosciences*, *109*(2), 171-199.

A percentile-based comparison of three individual measuring techniques of coarse-grained fluvial deposits from vertical outcrops

Garefalakis, Philippos*[(1)], Do Prado, Ariel [(1)], Mair, David [(1)],
Nyffenegger, Franziska [(2)], Schlunegger, Fritz [(1)]

[(1)] *University of Bern, Institute of Geological Sciences, Baltzerstrasse 1+3, CH-3012 Bern*
[(2)] *Berner Fachhochschule (BFH), Institut Siedlungsentwicklung und Infrastruktur ISI, Kompetenzbereich Geotechnik und Naturereignisse, Pestalozzistrasse 20, CH-3400 Burgdorf*

* Email address of corresponding author: philippos.garefalakis@geo.unibe.ch

Grain size measuring techniques for gravel (>2mm) have been widely used in numerous studies following different approaches. With the improvement of digital technologies and user-friendly applications in the past decades, measuring techniques shifted from time-consuming mechanical sieve approaches to measuring methods using digital photographs that became state-of-the-art. While these 'photo-sieving' methods are considered as a valid and representative grain size measuring technique for horizontal surfaces e.g. recent river deposits, only a few studies have investigated the application and accuracy of these methods on sedimentary deposits, e.g. the stratigraphic record of river deposits such as conglomerates from now exposed rock walls.

Here, we present a percentile-based comparison of three individual measuring techniques of coarse-grained deposits exposed at vertical outcrop walls. We analysed the material by i) measuring grain sizes by hand with a calliper, ii) measuring grain sizes on digital photographs and iii) by mechanically sieving the excavated material within an accredited laboratory (BFH in Burgdorf, Bern). For this experiment, we have chosen a gravel pit north of Bern where we focused on 2x4 individual outcrops within the same stratigraphic layer. We selected a gravel pit because the material can easily be excavated by minimal effort and as it offers a high visual, and architectural, similarity to stratigraphic outcrops such as conglomerates that are mostly exposed at steep walls. We especially aim to show that grain size measurements on digital photographs from vertical outcrops produce replicable results and are comparable to well-established techniques such as mechanical dry-sieving.

The following procedure should assure that the investigated clasts origin from the same spots within the totally eight outcrops, each covering an area of c. 1-2m^2. First, we marked the outcrop surface with colour and took digital photographs scaled with a meter stick, which we later used for the digital grain size measurements of the longest visible axis of 100 grains exposed at the outcrop wall. This has been done on computers using the image analysis software ImageJ. Second, we excavated the material and caught the material in buckets. From this material, we then measured by hand the longest-, intermediate- and shortest-axis of 100 blindly and randomly selected *coloured* grains, therefore assuring that we measured the same grains visible on the photographs. Third, we then used the bulk-sediments (including fines <2mm) for the mechanical dry-sieving. This step has been processed in the lab using a Haver EML 400 Digital Plus sieve shaker from Haver & Boecker OHG with square-hole sieve openings (125, 63, 31.5, 16, 8, 4, 2, 1, 0.5 mm and residual pan). For a direct comparison of the three individual techniques, we excluded the fines (material <2mm) from the sieving curves because i) the hand- and photo-measurements already prevented us from measurements of grains that are smaller than 2mm and ii) since we are interested in the coarse-grained material

(>2mm) only. We are furthermore interested in the intermediate (b-) axis, because this is the axis passing square-hole sieve openings during the sieving procedure and because the b-axis has been calibrated with hydrological formulas that are of interest for various applications arising from the grain size dataset. For each merged twin-outcrop and measuring procedure, we calculated the D_{16}, D_{50} and D_{84} grain size percentiles and cross-compared them (note: in case of the sieving data, we translated weight-percentage into percentiles by linearly interpolating the sieving-curves).

Our results show that the comparison between the hand- (b-axis) and photo- (longest visible axis) measurements are *in average* not in good agreement, at least for the D_{16} and D_{50} percentiles, which we both underestimated on the photographs by 57.9 ± 5.9% (D_{16}) and 31.1 ± 8.7% (D_{50}). The D_{84} in average is in good agreement and we only underestimate it by 0.8 ± 7.9% on the photos. We infer that the underestimation on the photos can partly be explained by a hiding/burial effect, where larger grains tend to cover smaller ones and thus not allow their full exposure on the images. Thus larger grains are also easier to be identified on images, which explains the good agreement with the D_{84}. In addition, measurements by hand introduce a selective bias and larger grains (i.e. contributing to the D_{84}) are more likely to be picked up, therefore minimizing the underestimation of this percentile, while smaller grains are more likely to be skipped unintentionally.

Upon comparing the hand- and sieving-measurements (both b-axis), we observed a similar pattern. The D_{16} is underestimated by the sieving compared to the hand-measurement by 54.8 ± 7.3%, and the D_{50} by 27.3 ± 10.6%, while the D_{84} is in good agreement with an overestimation by hand of 7.6 ± 10.3%. Again, we interpret that the selective bias while measuring by hand (manifested by picking up larger grains) plays here a crucial role. Beside this, square-hole sieve openings are more likely to bypass flatter grains, which in turn have a larger b-axis. Thus instead of being accounted to the larger sieve, flat grains are retained in the smaller, lower sieve, while spherical grains are held-back in the larger sieve (however having a smaller b-axis compared to the flatter grains). We suppose that the grains contributing to the smaller percentiles (D_{16}, D_{50}) are flatter compared to the grains contributing to larger percentiles (D_{84}). However, further investigations on the grain shape across all percentiles are necessary to confirm this assumption.

Finally, upon comparing the sieve- (b-axis) with the photo- (longest visible axis) measurements, we found a very good agreement for all three percentiles of interest. The D_{16} is underestimated in the photo-measurement by ca. 7.2 ± 8.3%, while the D_{50} is underestimated by ca. 5.4 ± 4.2%. The D_{84} is however slightly overestimated (7.6 ± 7.6%) on the photos compared to the sieve data. From this, we conclude that the longest visible axis from the photo-measurements convincingly corresponds to the b-axis retained during the sieving procedure. Since we are interested in finding a 'quick-and-efficient' method for approximating the b-axis using a time-saving and user-friendly approach, we consider the photo-measuring technique as very effective and replicable to the stratigraphic record or vertically exposed outcrop walls.

Nano-scale pathways of modern dolomite formation in Lake Neusiedl, Austria: insights from high-resolution transmission electron microscopy

Patrick Meister*(1), Silvia Frisia(2), Péter Pekker(3), Zsombor Molnár(3), Stephanie Neuhuber(4), Susanne Gier(1), Attila Demény(5), and Mihály Pósfai(3)

(1) *Department of Geology, University of Vienna, Josef-Holaubek-Platz 2, 1090 Vienna, Austria*
(2) *School of Environmental and Life Sciences, The University of Newcastle, Callaghan, New South Wales, 2308, Australia*
(3) *University of Pannonia, Research Institute of Biomolecular and Chemical Engineering, Egyetem u. 10, 8200 Veszprém, Hungary*
(4) *Institute of Applied Geology (IAG), University of Natural Resources and Life Sciences, Peter-Jordan-Straße 82, 1190 Vienna, Austria*
(5) *Institute for Geological and Geochemical Research, Hungarian Academy of Science, Budaörsi u. 45, 1112 Budapest, Hungary*

* Email address of corresponding author: patrick.meister@univie.ac.at

Dolomite [$Ca,Mg(CO_3)_2$] formation under Earth surface conditions is considered largely inhibited by a kinetic barrier. Yet, dolomite is commonly observed to form in modern lacustrine environments. We present a high-resolution transmission electron microscope analysis of dolomite from Lake Neusiedl / Fertő, an evaporative lake at the Austrian-Hungarian border. A variety of differently ordered Ca/Mg-carbonate structures appear in bulk X-ray diffraction spectra. Energy-dispersive X-ray analyses show various types of concentric zoning of Mg-rich and Mg-poor zones in micrometre-sized crystals. Within the Mg-rich domains, high-resolution transmission electron microscopy revealed few-nanometre-sized domains, possessing a high degree of ordering, with alternating Ca-rich and Mg-rich lattice planes (dolomite-structure) in coherent orientation with the surrounding Mg-calcite. These nano-structures suggest several potential growth pathways: (i) ordered domains induced by oscillating conditions at the growing crystal surface, (ii) oriented attachment and incorporation of nanocrystals (cf. Meister and Frisia, 2019), or (iii) inhomogeneities inherited during ripening via recrystallization. The observed nano-structures provide a snapshot in the ongoing evolution of dolomite formation. However, the ripening is probably episodic. A precursor phase may have been precipitated at high supersaturation in the water column and ripened due to a decrease in supersaturation relative to the precursor near the sediment-water interface (Fussmann et al., 2020). The mineral assemblage will be preserved as long as the sedimentary porewater remains supersaturated with respect to the metastable phase. Following Ostwald's step rule, ripening may proceed as the metastable phase becomes undersaturated.

References

Fussmann, D., von Hoyningen-Huene A.J.E., Reimer, A., Schneider, D., Arp, G., Daniel, R., Babková, H., Peticzka, R., Maier, A., Meister, P. (2020) Authigenic formation of Mg-Ca-carbonates in shallow alkaline water in Lake Neusiedl, Austria. Biogeosciences 17: 2085–2106.

Meister, P. and S. Frisia (2019). "Dolomite formation by nanocrystal aggregation in the Dolomia Pricipale of the Brenta Dolomites (Northern Italy)." Rivista Italiana di Paleontologia e Stratigrafia (Research in Paleontology and Stratigraphy) 125(1).

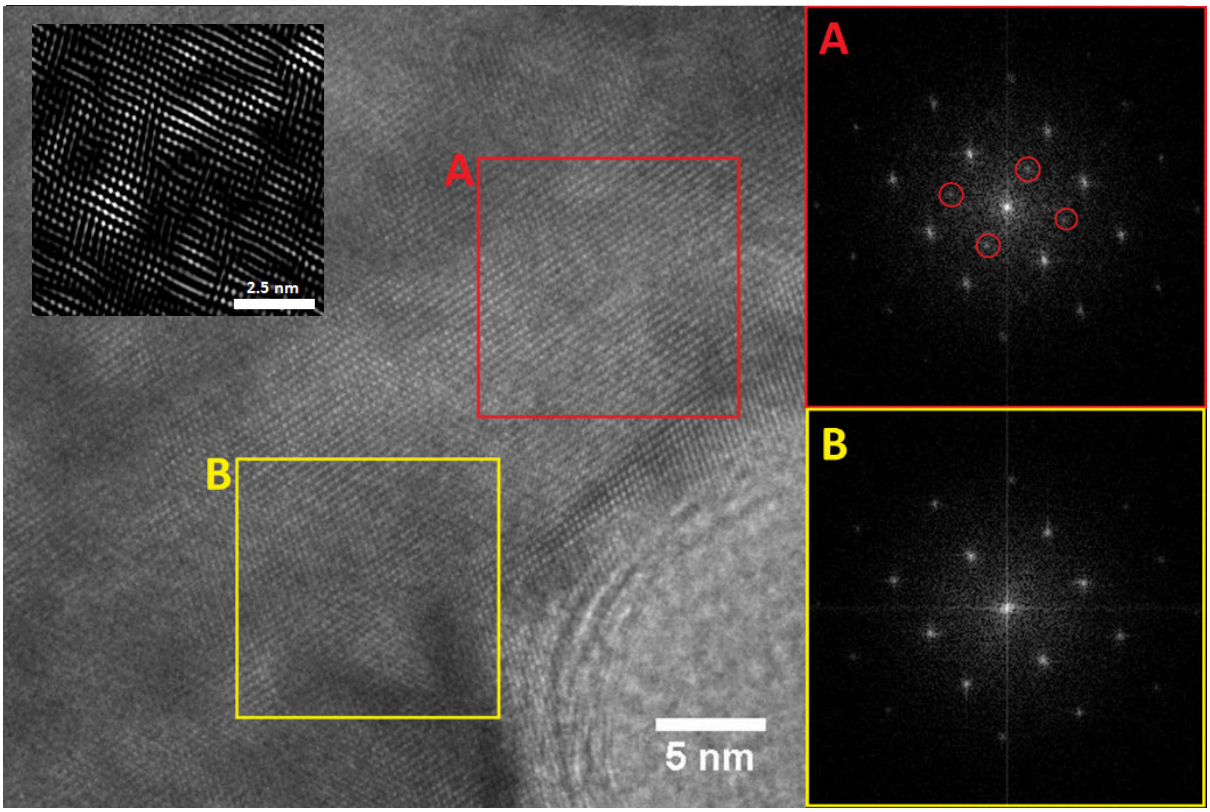


Figure 1. High-resolution transmission electron microscope image of authigenic Mg/Ca carbonate from Lake Neusiedl / Fertő (Austria/Hungary). The red and yellow marked areas show contrasting Fourier Transforms: in (A) dolomitic ordering is present (as indicated by the presence of reflections marked by red circles), in (B) not.
Inverse Fourier transformation using only the signal from the dolomitic ordering reflections (inset, upper left) reveals ca. two-nm scale, dolomitic domains. The crystal lattice is in crystallographic continuation with the surrounding Mg-calcite.

Formation and Middle Triassic dissolution of Middle Muschelkalk halite deposits in Northern Switzerland

Pietsch, Johannes *[1, 2], Wetzel, Andreas [1], Deplazes, Gaudenz [3], Filipponi, Marco [3]

[1] *University of Basel, Department of Environmental Sciences, Bernoullistrasse 32, CH-4056 Basel, Switzerland*
[2] *Schweizer Salinen AG, Rheinstrasse 52, CH-4133 Pratteln, Switzerland*
[3] *Nagra, Hardstrasse 73, CH-5430 Wettingen, Switzerland*

* Email address of corresponding author: johannes.pietsch@unibas.ch

Middle Muschelkalk evaporites are of economic as well as geotechnical interest. Practically the entire salt supply in Switzerland is ensured from Middle Muschelkalk halite deposits which have been mined in northern Switzerland for almost 200 years. Due to the high solubility of the evaporites, various hydrogeological and geotechnical issues can potentially arise. In addition to gypsum swelling, increased subsidence due to solution processes in the subsurface may cause geotechnical challenges under certain hydrogeological conditions. Many studies therefore deal with the halite deposits in northern Switzerland and adjacent regions and provide attempts to explain the regional distribution of these deposits. Nevertheless, still today our understanding of the formation and distribution of the halite deposits, as well as the processes that enabled or prevented the preservation of halite, is only fragmentary.

In the context of a recent campaign of deep boreholes drilled by Nagra ("National Cooperative for the Disposal of Radioactive Waste"), 560 m of drill cores of the Middle Muschelkalk Zeglingen Formation from nine boreholes were sedimentologically logged. This allows a more detailed analysis of the Triassic formation of the Muschelkalk succession in this area.

Based on the detailed logging, 22 lithofacies and 10 lithofacies associations of Middle Muschelkalk evaporites were defined. High-resolution regional correlations of gamma-ray logs from the different drillings show substantial thickness variation of the succession. Locally, sedimentological drill core observations indicate solution processes (collapse breccias and ductile deformed horizons). In combination, the latter processes can be dated to Middle Triassic times. More precisely, they occurred immediately after deposition (eogenetic) and during ongoing deposition of the Middle and Upper Muschelkalk in depths of tens of meters (eo- to mesogenetic). Locally the amount of this Middle Triassic dissolution can be quantified to be smaller than 20 m.

The observation of halite dissolution points towards subsurface fluid flow, likely connected to deeper seated faults. Together with the regional thickness variation of the Muschelkalk succession this suggests a tectonically active depositional environment in the Middle Triassic.

The presented study extends the knowledge of spatial and temporal depositional evolution of the Middle Muschelkalk in northern Switzerland. A model conception explains distribution and thickness of the halite beds, and findings on the Middle Triassic dissolution history. Whereas the observed dissolution processes in the study area have terminated by the Triassic times, the observed processes involved can serve as analogue for investigations elsewhere.

From sea to a saline desert: the story of the late Pleistocene to Holocene desiccation of the Danakil Depression, Afar, Ethiopia

Rime, Valentin*[(1)], Foubert, Anneleen[(1)], Fentimen, Robin[(2)], El Korh, Afifé[(1)], Negga, Haileyesus[(1)], Pinkenseer, Claudius[(1)], Hajdas, Irka[(3)], Adatte, Thierry[(4)], Atnafu, Balemwal[(5)], Kidane, Tesfaye[(6)],

[(1)] *University of Fribourg, Dep. of Geosciences, Chemin du Musée, CH-1700 Fribourg, Switzerland*
[(2)] *Observatoire du Patrimoine Naturel Littoral, Terre Plein de l'Ecluse, 50400 Granville, France*
[(3)] *ETH Zürich, Dep. of Earth Sciences, Otto-Stern-Weg, 8093 Zürich, Switzerland*
[(4)] *University of Lausanne, Faculty of Geosciences and Environment, Géopolis, Lausanne, Switzerland*
[(5)] *Addis Ababa University, School of Earth Sciences, Addis Ababa, Ethiopia*
[(5)] *University of KwaZulu-Natal, School of Agricultural, Earth and Environmental Sciences, Durban, South Africa.*

* Email address of corresponding author: valentin.rime@unifr.ch

The formation of salt giants remains an actively debated topic. Several mechanisms are invoked to explain the thick evaporite successions found in many sedimentary basins around the world. It has been argued that the lack of modern analogues prevents an actualistic approach to the problem. Yet, the Danakil depression in northern Afar (Ethiopia) features a thick (up to 2000 m) evaporite sequence where halite is still depositing nowadays.

This study presents a 600 m Pleistocene to Holocene core record drilled in the center of the Danakil basin. A multi-proxy analysis (facies, geochemistry, mineralogy, organic carbon content, micropaleontology and dating) allowed to identify the alternation of different mechanisms explaining the thick evaporite succession: marine seawater evaporation, evaporation of saline pans (playas), continental reworking of salts, seepage and hydrothermal fluid circulation. The age of the sediments was constrained thanks to the correlation between the core facies and the sediments outcropping at the margin of the basin. Most of the evaporite deposition took place after the MIS 5e Red Sea transgression in the basin. The deposition continued until now, recording also major environmental changes during the late Pleistocene to Holocene, such as the African Humid Period.

This study has been funded through the Swiss National Science Foundation (SNF project SERENA – SEdimentary REcord of the Northern Afar 200021_163114).

Bajocian coral reefs of the "Herrenwis Unit" in North- Eastern Switzerland

Arnaud Ruchat[1], Bernard Lathuilière[2], Stephan Wohlwend[3], Gaudenz Deplazes[4], Herfried Madritsch[4], Gregor P. Eberli[5], Ovie E. Eruteya[1], Elias Samankassou[1]

1 Department of Earth Sciences, University of Geneva, Rue des Maraîchers 13, 1205 Geneva, Switzerland
2 Université de Lorraine, CNRS, Lab. GeoRessources, UMR 7359, BP 70239, 54506 Vandoeuvre-lès-Nancy Cedex, France
3 Geological Institute, ETH Zürich, Sonneggstrasse 5, 8092 Zürich, Switzerland
4 National Cooperative for the Disposal of Radioactive Waste (Nagra), Hardstrasse 73, 5430 Wettingen, Switzerland
5 Department of Marine Geosciences, Rosenstiel School of Marine and Atmospheric Science, University of Miami, FL 33149, USA

Within the framework of the "Sachplan Geologische Tiefenlafer" (SGT), Nagra is currently investigating three sites in northern Switzerland as potential repositories for radioactive waste. The host rock, the Opalinus Clay, and its containment stratigraphic units are being explored by deep drilling and 3D seismic analysis.

In the Nördlich Lägern study area, 2D seismic data have already revealed a rounded paleohigh in the Middle Jurassic upper confining units of the Opalinus Clay (Meier & Deplazes, 2014) and later confirmed by 3D seismic data. The recently drilled Nagra borehole Bülach-1 within this paleohigh shows well- preserved corals above the Wedelsandstein Formation respectively a thin "Humphriesi-Oolith Formation". This new unit is informally named "Herrenwis Unit."

This unit is further investigated in the presented study by an integrative analysis of the currently available 3D seismic reflection data and well data and cores available from the study area.

Seismic geomorphological interpretation of the 3D seismic reflection data reveals a unique cluster of mound-shape structures interpreted as coral patch reefs. The development of these features on a pre-existing paleohigh indicates topographic control on their evolution. The individual mound structures are comparable in morphology and size.

The main coral genera identified are *Isastrea*, *Periseris*, *Thamnasteria* and *Dendraraea*. Preliminary assessment of the growth features and orientation of the corals, the presence of surrounding microbialites and the scarcity of transport features indicates that most corals are upright and occur in growth position. This reef is typical of the Bajocian, based on quantitative data using the coral diversity and abundance (Lathuilière, 2000a, b).

The identified "Herrenwis Unit" shows that coral reefs developed in Northern Switzerland, along with the Middle Jurassic marine oolitic carbonates and marly basinal deposits reported by Gonzalez & Wetzel (1996). This finding extends the occurrence of coral reefs, widely reported in the Tethyan realm and displaying comparable geometries (e.g., France and Morocco).

Ongoing research will help characterize the reef facies and its large-scale distribution.

References

Gonzalez, R., & Wetzel, A. 1996: Stratigraphy and paleogeography of the Hauptrogenstein and Klingnau Formations (middle Bajocian to late Bathonian), northern Switzerland]. Eclogae Geologicae Helvetiae, 89(1), 695-720. https://doi.org/10.5169/SEALS-167921

Lathuilière, B. 2000a: Coraux constructeurs du Bajocien inférieur de France. Geobios, 33(1), 51–72. https://doi.org/10.1016/S0016-6995(00)80149-7

Lathuilière, B. 2000b: Coraux constructeurs du Bajocien inférieur de France. Geobios, 33(2), 153–181. https://doi.org/10.1016/S0016-6995(00)80013-3

Meier, B., & Deplazes G. 2014: Reflexionsseismische Analyse des 'Braunen Doggers'. Nagra Arbeitsbericht. NAB 14-058. Nagra, Wettingen. 51 pp.

Determining the controls on flow behaviour, bedform development and stratigraphic architecture from detailed surveys and monitoring of active submarine channels

Daniela Vendettuoli

Institute of Geological Sciences, University of Bern

Turbidity currents transport sediment from shallow to deep water via submarine channels. These flows carry globally important volumes of sediment, and transport organic carbon, oxygenated waters, nutrients and contaminants that accumulate within submarine channels and at their terminal lobes or fans. Previous studies have largely relied upon the analysis of ancient deposits or scaled-down measurements of laboratory-scale flows to understand turbidity currents. Several conceptual models exist, but it remains unclear as to whether turbidity currents show a distinct behaviour at different scales, or if a continuum of behaviour exists from small to large events. Recent technological advances allow us to investigate these issues. The advent of Autonomous Underwater Vehicles enables mapping of the seafloor at unprecedented detail, repeat surveys record previously-unseen seascape changes, while Acoustic Doppler Current Profilers record the range of internal structures observed in field-scale turbidity currents for the first time. During my PhD, I used high-resolution data acquired in several modern offshore systems to analyse turbidity current behaviour across various spatial and temporal scales. First, I used a global analysis of direct velocity measurements of turbidity currents that reveals the possibility of two end-member modes of turbidity current behaviour ranging from: i) a sudden peak in velocity that decays exponentially, lasting minutes to hours; to ii) sustained flow that lasts for days. I showed that a continuum exists between these flow modes; likely controlled by the proportion of sand or mud within the flow. Second, I analysed an extensive (65 x 50 km) and detailed (5 m bin size) seafloor survey offshore East Africa, that reveals a variety of bedforms within two deep-sea canyons. Morphometric analysis reveals a continuum from small-scale (10s m wavelength) crescentic bedforms to large-scale (kms wavelength) sediment waves. This continuum is in contrast with a previous global study, but that study did include such high-resolution deep-water data. Previous studies may have missed an intermediate scale of bedform due to the decreasing resolution with increasing water depth-related. Small to medium-scale bedforms may be more common in the deep sea than currently thought. Third, I used repeat mapping of an active submarine delta to reveal how turbidity currents build stratigraphy. As a result of the reworking caused by repeated flows, the completeness of the stratigraphy record over three months is found to be 10% on average. The stratigraphic record is dominated by large events. Large slope failures are more likely to be preserved than smaller bedforms, while erosion is dominated by rare, but powerful turbidity currents that can obscure the record of smaller flows.

In conclusion my understanding is that a continuum in turbidity current behaviour exists across various scales of flow, from small fjord channel systems to the largest submarine channels on the planet. The mode of flow is dominantly controlled by the grain size of the sediment available in the system. The continuum in bedform scales reflects both the downstream evolution of turbidity currents, as they expand due to mixing with ambient seawater and entrainment of seafloor sediment, and modifications caused by seafloor morphology. What becomes recorded in stratigraphy does not show a gradual continuum, however, and instead appears to be strongly biased by larger but infrequent events.

The Late Holocene (Meghalayan) mega-drought Impact on the late Medieval Egypt: Geochemical and Palynological proxies from Inland Saline Lake Sediments at Wadi El-Natrun (Western Nile Delta, Egypt)

Amr S. Zaky[1, 2*], Hendrik Vogel[1], Flavio Anselmetti[1]

[1] Institute of Geological Sciences, Oeschger Centre for Climate Change Research, University of Bern, 3012 Bern, Switzerland
[2] Geology Department, Faculty of Science, Menoufia University, Shebin El-Kom 32511, Egypt

* Correspondence: amr.zaky@geo.unibe.ch or amrsaid86@science.menofia.edu.eg

The early Late Holocene ~ 4.2 cal. kyr BP was coupled with one of the most significant Holocene climate events known as “a global mega-drought event” and/or “4.2 ka event”. This event has been used to delineate the transition between middle (Northgrippian) to late-Holocene (Meghalayan). The impact of this event was strongly influenced by the geographical location. Geochemical and Palynological proxies have been applied on three inland saline lakes sediment cores located at Wadi El-Natrun (Western Nile Delta, Egypt) for the reconstruction of the Late Holocene-Recent climate variability and Nile flow history in the study area and their impacts on human settlement and activities. The radiocarbon dating results indicated that the oldest calibrated age for El-Beida sediment core is Late Holocene (786-679 cal. yr BP). The geochemical results showed that organic matter source of El-Gaar sediment archive is terrigenous coupled with anoxic environmental conditions. The Late Holocene sediments of El-Beida core revealed terrigenous source of organic matter associated with slightly oxic environmental conditions while the recent sediments showed aquatic and soil sources of organic matter associated with redox environmental conditions. The different geochemical parameters for Um-Risha sediment core indicated terrigenous source of organic matter coupled with oxic environmental conditions. The Palynological results for El-Beida sediment core enabled to reconstruct the vegetation history of the study area. The Late Holocene sediments of El-Beida showed increase in Poacae and Amaranthacae /Chenopodiacae and decrease in Cyperacae coupled with decrease in trees/shrubs group which may be attributed to the dominance of arid climatic conditions and permanent shift in rainfall and/or Nile flow followed the late Holocene Mega-drought event. On the other hand, the recent sediments of El-Beida reflected slightly increase in the humid conditions but in a general arid climate trend due to the increase of Cyperacae coupled with slightly increase of trees/shrubs and the decrease of Poacae. Moreover, the increase of charcoal may give indication to the increase in recent anthropogenic activities in the study area.

Harmonisation of Opalinus Clay descriptions in Northern Switzerland: towards a uniform Subfacies Classification Scheme

Géraldine Zimmerli*[(1)], Bruno Lauper[(1)], Gaudenz Deplazes[(2)], David Jaeggi[(3)], Stephan Wohlwend[(4)], & Anneleen Foubert[(1)]

[(1)] *Department of Geosciences, University of Fribourg, 1700 Fribourg, Switzerland*
[(2)] *Nagra, 5430 Wettingen, Switzerland*
[(3)] *Federal Office of Topography swisstopo, 3084 Wabern, Switzerland*
[(4)] *Geological Institute, ETH Zurich, 8092 Zürich, Switzerland*

* geraldine.zimmerli@unifr.ch

The Opalinus Clay, an argillaceous to silty claystone formation, is known in Switzerland as being the selected host rock for deep geological disposal of high-, intermediate- and low-level radioactive waste. Since the 1990s, various properties of the Opalinus Clay have been studied within the framework of the Nagra (National Cooperative for the Disposal of Radioactive Waste) deep drilling campaigns and the Mont Terri Project (international research program dedicated to the investigation of claystone). The Opalinus Clay succession was deposited during the Late Toarcian to Early Aalenian in an epicontinental sea covering central Europe.
The Opalinus Clay is relatively homogeneous at formation-scale compared to other Mesozoic formations in northern Switzerland. At higher spatial resolution however, sedimentological variations do occur. Besides m-scale lithofacies variations, high, intra-facies lithological variability occur at dm- to cm-scale. The facies diversity is primary attributed to regional differences in depositional, environmental and diagenetic conditions. In order to harmonize petrographic descriptions in an objective and quantitative way within all fields of research related to the Opalinus Clay, a subfacies classification scheme has been developed (Lauper et al., 2018, 2021). The subfacies are distinguished by parameters such as texture (grain size, bedding, fabric and colour) and composition (nature and mineralogy of components). The five subfacies types can be further refined by additional attributes and sedimentary characteristics (biogenic, diagenetic, structural).
Subfacies descriptions are crucial to understand the lateral and vertical facies variability at regional scale. Moreover, accurate petrographic descriptions are a crucial prerequisite to many geotechnical studies and the predictive modelling of petrophysical properties.
The main goal of the present study is to define a subfacies classification model covering the entire Opalinus Clay succession of the Mont Terri rock laboratory and successions deposited further to the east where Nagra is currently investigating three potential sites for radioactive waste storage within the Opalinus Clay. Nine new drill cores are used to apply the subfacies classification scheme. The current subfacies classification scheme will be adapted considering regional facies heterogeneities. Based on the revised subfacies classification, facies and intra-facies variability will be captured. This will form the base for the revision of depositional models for the Opalinus Clay using a basin-wide approach.

References:

Lauper, B., Jaeggi, D., Deplazes, G., & Foubert, A. (2018). Multi-proxy facies analysis of the Opalinus Clay and depositional implications (Mont Terri rock laboratory, Switzerland). Swiss Journal of Geosciences, 111, 383-398. https://doi.org/10.1007/s00015-018-0303-x

Lauper, B., Zimmerli, G.N., Jaeggi, D., Deplazes, G., Wohlwend, S., Rempfer, J., & Foubert, A. (2021). Quantification of lithological heterogeneity within Opalinus Clay: toward a uniform subfacies classification scheme using a novel automated core image recognition tool. Frontiers in Earth Science, 9, 645596. https://doi.org/10.3389/feart.2021.645596.