Universität zu Köln

DFG Deutsche Forschungsgemeinschaft
German Research Foundation

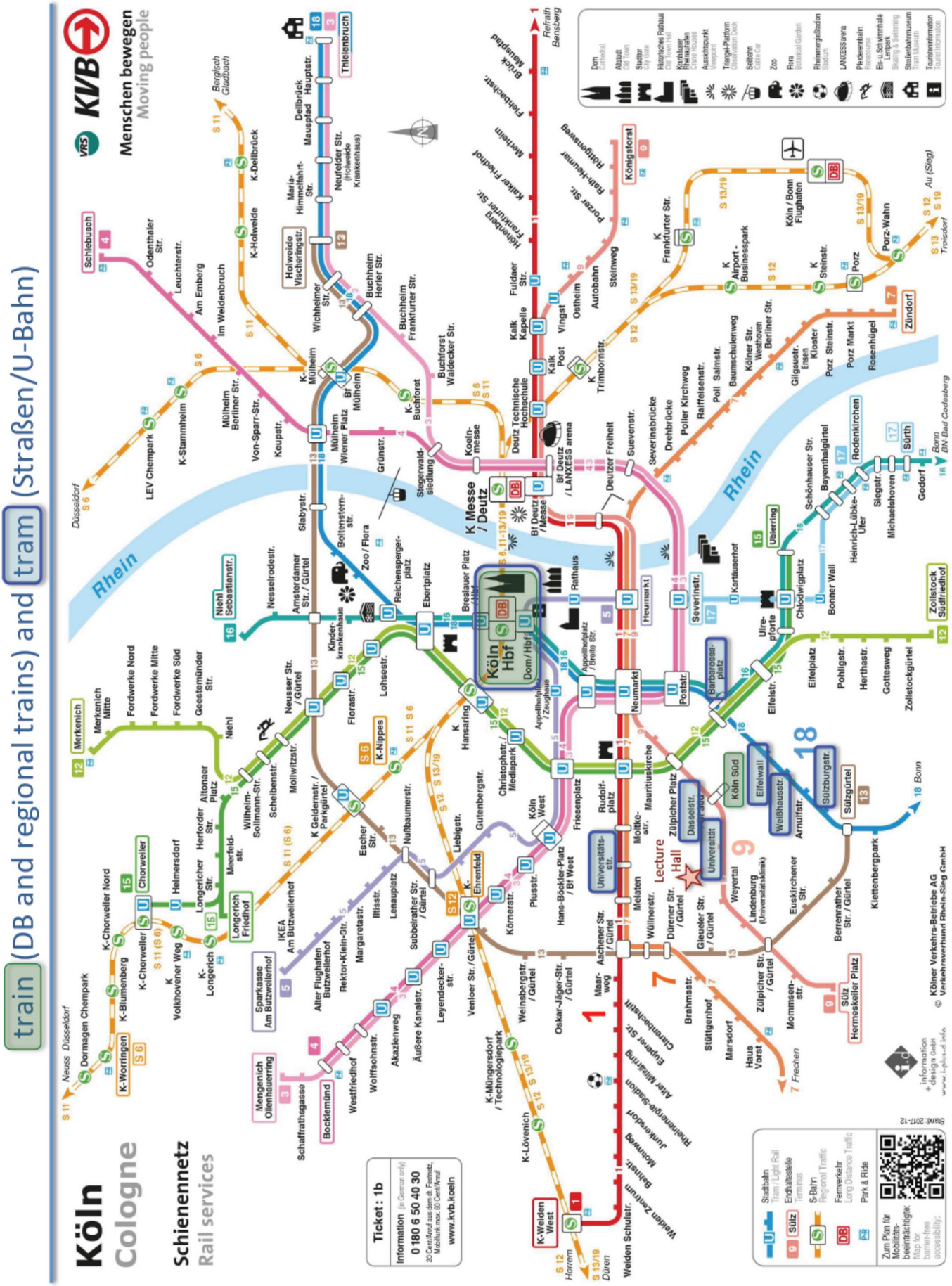
IODP/ICDP Kolloquium 2019

Universität zu Köln

18. – 20. März 2019

icdp

IODP
INTERNATIONAL OCEAN DISCOVERY PROGRAM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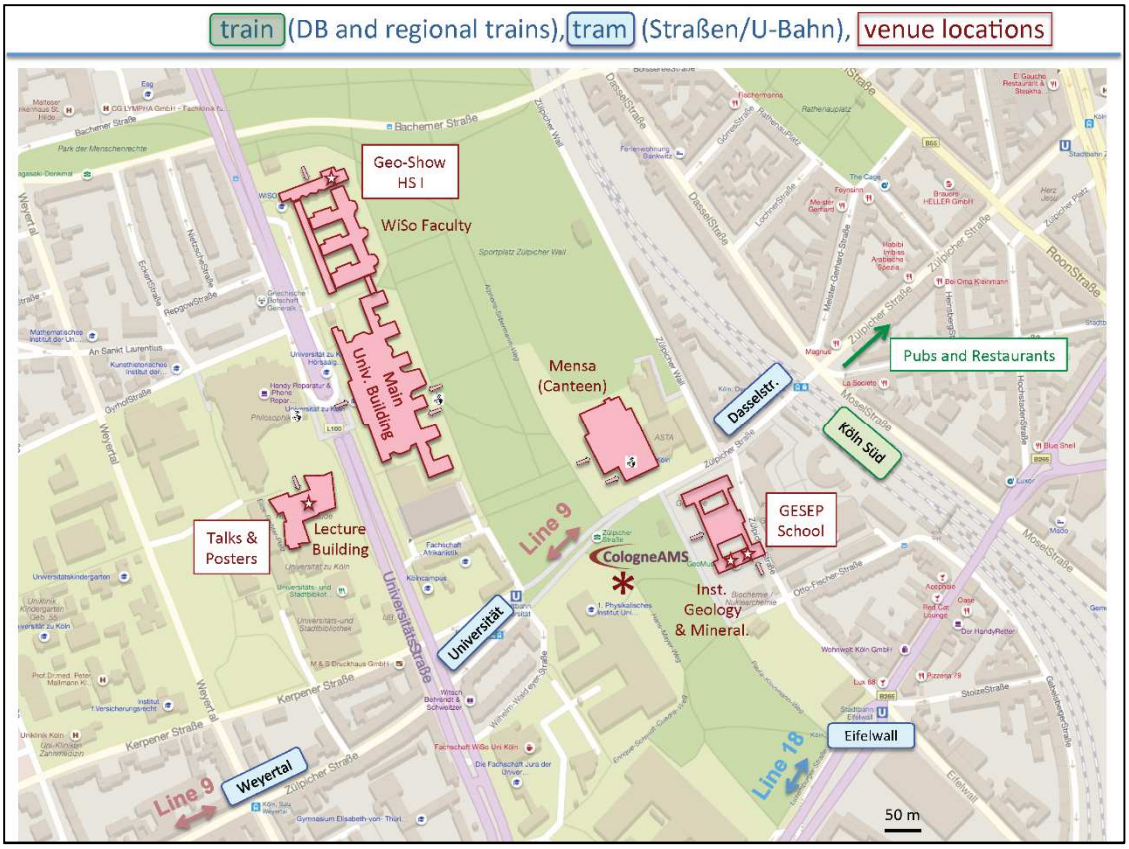
train (DB and regional trains), tram (Straßen/U-Bahn), venue locations



Tagungsprogramm – *Agenda*

Montag, 18. März 2019 – *Monday March 18th, 2019*

08:30	13:30	Registrierung - *Registration*
Parallel stattfindend:		
10:30	**12:00**	***Geo-Show "Unterirdisch": im Hörsaal I der WiSo-Fakultät der Uni, Universitätsstr. 24, 50931 Köln***
Beginn Kolloquium – Beginning of conference		
13:30	13:50	*Begrüßung - Reception*
13:50	14:10	***Bohnhoff, Marco/ Krastel, Sebastian*** *ICDP Rückblick auf 2018 - Wie geht es weiter?*
14:10	14:30	***Erbacher, Jochen/ Bornemann, André*** *IODP Rückblick auf 2018 - Wie geht es weiter?*
Wissenschaftliche Beiträge zu IODP und ICDP – scientific talks related to IODP and ICDP		
14:30	14:50	***Bergmann, Fenna*** *The HimalFan project – The Quantification of Himalayan Erosion Fluxes from the Bengal Fan record based on seismic stratigraphy and geochemical analyses*
14:50	15:10	***Bretschneider, Lisa*** *Indian Monsoon induced erosion during the Miocene recorded at IODP Site U1443 (Exp. 353)*
15:10	16:20	***Posterpräsentation und Kaffeepause – Presentation of posters and coffee break***
16:20	16:40	***Panagiotopoulos, Konstantinos*** *Pollen- and biomarker-inferred climate at Lake Ohrid in the Early Pleistocene*
16:40	17:00	***Neugebauer, Ina*** *TEPH-ME: CryptoTEPHrochronology in the ICDP Dead Sea deep core as a key to synchronise past hydroclimate changes in the eastern Mediterranean*
17:00	17:20	***Gischler, Eberhard*** *Geomorphology of the Belize Barrier Reef margin: a survey for IODP drilling*
17:20	17:40	***Drury, Anna Joy*** *Achieving a global late Miocene stable oxygen isotope reference stratigraphy spanning 8.00-5.33 Ma*
17:40	18:00	***Diekmann, Bernhard*** *Palaeoenvironmental Messages from Lake Teletskoye, Sibirian Altay Mountains: State of Findings and future Perspectives .*
Im Anschluss: Posterpräsentation und ICEBREAKER:– Presentation of posters and ICEBREAKER: Hörsaalgebäude, Universitätsstrasse 35, 50931 Köln		

Dienstag, 19. März 2019 – *Tuesday, March 19th, 2019*

Fahrtberichte IODP – *Cruise Reports IODP*		
09:00	09:20	***Brandl, Philipp A.*** *IODP Expedition 376 Brothers Arc Flux*
09:20	09:40	***Esper, Oliver:*** *IODP Expedition 374: Ross Sea West Antarctic Ice Sheet History*
09:40	10:00	***Kutterolf, Steffen*** *Unlocking the secrets of slow slip by integrating core data, seismic and mechanical experiments, as well as borehole observatories at the offshore Hikurangi subduction zone, IODP Expeditions 372 & 375*

10:00	10:20	***Seguin, Joana*** *IODP Expedition 381: Development of the active Corinth Rift*
Wissenschaftliche Beiträge zu IODP und ICDP - *scientific talks related to IODP and ICDP*		
10:20	10:40	***Zimanowski, Bernd*** *Forschungsbohrung auf Surtsey Experimentelle Untersuchungen zur Entstehung und der thermischen Geschichte (SUSTAIN)*
10:40	11:10	***Posterpräsentation und Kaffeepause - Presentation of posters and coffee break***
11:10	11:30	***Schubotz, Florence*** *Abiotic substrate generation and microbial-life signatures close to the temperature limit of life, IODP Expedition 370*
11:30	11:50	***Zhang, Junli*** *Near lithostatic pore pressures prepare the Nankai décollement for the next megatsunami offshore SW Japan*
11:50	12:10	***Dinske, Carsten*** *Rupture Imaging and Directivity of the 2014 M5.5 Earthquake Below a Gold Mine in Orkney, South Africa*
12:10	12:30	***Heeschen, Katja*** *IODP Site U1517: Insights from hydrocarbon measurements into the gas-hydrate bearing slope sediments at the Toaheni Landslide Complex (TLC) offshore New Zealand.*
12:30	14:00	***Mittagspause und Posterpräsentationen - Presentation of posters and coffee break***
14:00	14:20	***Zhang, Chao*** *Experiments on melt-peridotite interaction at crust-mantle boundary: Implications for heterogeneity in the lower crust*
14:20	14:40	***Davis, Timothy*** *Can we predict fluid pathways in the crust?*
14:40	15:00	***Schwarzenbach, Esther M*** *Tracking water-rock interaction at the Atlantis Massif (MAR, 30°N) using sulfur geochemistry*
15:00	15:20	***Kästner, Felix*** *Core-log-seismic data integration to improve the seismic stratigraphy within the ICDP drilling project COSC-1, Sweden: challenges and first results*
15:20	16:30	***Posterpräsentation und Kaffeepause - Presentation of posters and coffee break***
16:30	16:50	***Schäbitz, Frank*** *Good times for leaving home? The paleoenvironment of Chew Bahir in south Ethiopia: implications for human evolution, dispersal and technological innovation*
16:50	17:10	***Lüdecke, Tina*** *Early hominin dietary adaptation in diverse savanna ecosystems*
17:10	17:30	***Hasberg, Ascelina*** *Sediment core analyses from ICDP TDP Site 2, Lake Towuti (Indonesia): Characterization of mass movement deposits today and in the past. - Which information can we gain for other (lake) sediment studies?*
17:30	17:50	***Kallmeyer, Jens*** *Methanogenesis dominates organic matter mineralization in modern ferruginous sediments*
17:50	18:10	***Uenzelmann-Neben, Gabriele*** *Onset and modifications in intensity and pathways of water mass exchange between the Southeast Pacific and the South Atlantic with focus on the Falkland Plateau*
Ab 19:30		***Gemeinsames Abendessen – joint conference dinner: Brauhaus Unkelbach, Luxemburger Str. 260, 50937 Köln***

Mittwoch, 20. März 2019 – *Wednesday, March 20th, 2019*

Wissenschaftliche Beiträge zu IODP und ICDP - *scientific talks related to IODP and ICDP*		
09:00	09:20	***Haberzettl, Torsten*** *The Nam Co Drilling Project, Tibet (NamCore): A one million year sedimentary record from the third pole*
09:20	09:40	***Schulze, Nora*** *Seismostratigraphic analysis of high-resolution 2D data from Nam Co, Tibetan Plateau*
09:40	10:00	***Brzelinski, Swaantje*** *Mechanisms of glacial/interglacial climate variability during the Late Oligocene*
10:00	10:20	***Link, Jasmin M.*** *Interhemispheric Gradient of Nd isotopes in the Deep Atlantic Ocean since 800 ka*
10:20	11:10	***Posterpräsentation und Kaffeepause - Presentation of posters and coffee break***
11:10	11:30	***Thomas, Ariel*** *Simulating Submarine Fresh Groundwater Preservation Offshore New Jersey*
11:30	11:50	***Steinhoff, Christoph*** *Flow cytometry for purification of fossil pollen from Lake Van for AMS radiocarbon dating – a new approach*
11:50	12:10	***Prokopenko, Alexander*** *A Late Pliocene paleorecord from the extinct Lake Idaho, USA – a progress report*
12:10		***Posterprämierung und Schlussworte – Poster Awards and Concluding Remarks***
13:00	**GESEP School - Lake Sediment Drilling, Core Processing and Geochronology im Institut für Geologie und Mineralogie, Universität zu Köln**	

The key aspects of this course will comprise:

1. Lacustrine sediments as paleoenvironmental archives
2. Sediment core correlation and core processing
3. Geochronological methods for Quarternary sediments
4. Age-depth model development

Ende: Donnerstag, 21. März 2019 – *End March 21st, 2019*

Teilnehmerliste – *Participants*

Name *Surname*	Vorname *Given Name*	Institution und Ort *Affilation and Place*
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Institut für Geographie und Geologie (Uni Greifswald), Greifswald
		Geowissenschaften (FB5 Uni Bremen), Bremen
		Institut für Geowissenschaften (Uni Heidelberg), Heidelberg
		Helmholtz-Zentrum für Ozeanforschung (GEOMAR), Kiel
		Alfred-Wegener-Institut Helmholtz Zentrum für Polar- und Meeresforschung, Potsdam
		Institut für Geowissenschaften (Uni Heidelberg), Heidelberg
		Helmholtz-Zentrum für Ozeanforschung (GEOMAR), Kiel
		Geowissenschaften (FB5 Uni Bremen), Bremen
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Institut für Geowissenschaften (Uni Heidelberg), Heidelberg
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover
		Rabanus-Maurus-Schule Fulda, Fulda
		Helmholtz-Zentrum für Ozeanforschung (GEOMAR), Kiel
		Helmholtz-Zentrum für Ozeanforschung (GEOMAR), Kiel
		Institut für Chemie und Biologie des Meeres (ICBM - Uni Oldenburg), Oldenburg
		Institut für Geowissenschaften (Uni Heidelberg), Heidelberg
		Leibniz-Institut für Angewandte Geophysik (LIAG), Hannover
		Mineralogie, Petrologie und Geochemie (Uni München), München
		Institut für Geowissenschaften (Uni Heidelberg), Heidelberg
		Netherlands Institute of Ecology, Wageningen
		Geowissenschaften (FB5 Uni Bremen), Bremen
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Energie und mineralische Ressourcen Gruppe (RWTH Aachen), Aachen
		Hessische Staatskanzlei, 65183 Wiesbaden
		Zentrum für Marine Umweltwissenschaften (MARUM), Bremen
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		Alfred-Wegener-Institut Helmholtz Zentrum für Polar- und Meeresforschung, Potsdam
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		Leibniz-Institut für Angewandte Geophysik (LIAG), Hannover
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		Helmholtz-Zentrum für Ozeanforschung (GEOMAR), Kiel
		Institut für Bodenkunde (Uni Hannover), Hannover
		Institut für Geologie und Mineralogie (Uni Köln), Köln
		Institut für Geowissenschaften (Uni Potsdam), Potsdam
		Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover

Name *Surname*	**Vorname** *Given Name*	**Institution und Ort** *Affilation and Place*
		Mineralogie und Geodynamik (Uni Tübingen), Tübingen
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		Institut für Geophysik und Geologie (IGG - Uni Leipzig), Leipzig
		Helmholtz-Zentrum für Ozeanforschung (GEOMAR), Kiel
		Institut für Geographiedidaktik (Uni Köln), Köln
		Helmholtz-Zentrum für Ozeanforschung (GEOMAR), Kiel
		Institut für Umweltphysik (Uni Heidelberg), Heidelberg
		Institut für Geowissenschaften (Uni Heidelberg), Heidelberg
		Leibniz-Institut für Angewandte Geophysik (LIAG), Hannover
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		Alfred-Wegener-Institut Helmholtz Zentrum für Polar- und Meeresforschung, Bremerhaven Institut für Geologie und Mineralogie (Uni Köln), Köln
		Alfred-Wegener-Institut Helmholtz Zentrum für Polar- und Meeresforschung, Bremerhaven Institut für Geowissenschaften (Uni Potsdam), Potsdam
		Institut für Mineralogie (Uni Münster), Münster
		Institut für Geographie und Geologie (Uni Greifswald), Greifswald
		Zentrum für Marine Umweltwissenschaften (MARUM), Bremen
		Institut für Mineralogie und Lagerstätten (RWTH Aachen), Aachen
		Institut für Geologie und Mineralogie (Uni Köln), Köln
		Helmholtz-Zentrum für Ozeanforschung (GEOMAR), Kiel
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Alfred-Wegener-Institut Helmholtz Zentrum für Polar- und Meeresforschung, Bremerhaven Institut für Geowissenschaften (Uni Frankfurt), Frankfurt am Main
		Alfred-Wegener-Institut Helmholtz Zentrum für Polar- und Meeresforschung, Potsdam
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		Zentrum für Marine Umweltwissenschaften (MARUM), Bremen
		Institut für Geologie und Mineralogie (Uni Köln), Köln
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		School of Earth Sciences (Bristol), Bristol (UK)
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		Zentrum für Marine Umweltwissenschaften (MARUM), Bremen
		Institut für Geowissenschaften (Uni Heidelberg), Heidelberg
		Institut für Geowissenschaften (Uni Jena), Jena
		Institut für Ökologie, Evolution und Diversität (Uni Frankfurt), Frankfurt am Main
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		Institut für Geowissenschaften (Uni Heidelberg), Heidelberg
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Institut für Geowissenschaften (Uni Heidelberg), Heidelberg
		Institut für Geologie und Mineralogie (Uni Köln), Köln
		Institut für Geologie (Uni Hamburg), Hamburg
		Alfred-Wegener-Institut Helmholtz Zentrum für Polar- und Meeresforschung, Bremerhaven
		Institut für Geowissenschaften (Uni Heidelberg), Heidelberg
		Institut für Geowissenschaften (Uni Heidelberg), Heidelberg
		Institut für Geowissenschaften (IfG Geophysik - Uni Kiel), Kiel
		Zentrum für Marine Umweltwissenschaften (MARUM), Bremen
		Institut für Geowissenschaften (IfG - Uni Kiel), Kiel
		Institut für Erdwissenschaften, Universität Graz, A-8010 Graz
		Helmholtz-Zentrum für Ozeanforschung (GEOMAR), Kiel
		CAU Kiel, Leibniz Laboratory for Radiometric Dating and Stable Isotope Research, Kiel
		Institut für Geophysik und Geoinformatik (TU Freiberg), Freiberg
		Das GeoZentrum Nordbayern (Uni Erlangen), Erlangen
		Institut für Geologie und Mineralogie (Uni Köln), Köln
		Institut für Geowissenschaften (IfG Geophysik - Uni Kiel), Kiel
		Institut für Umweltphysik (Uni Heidelberg), Heidelberg
		Institut für Mineralogie (Uni Hannover), Hannover
		Institut für Geowissenschaften (Uni Heidelberg), Heidelberg
		Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover
		Senckenberg Biodiversität und Klima Forschunsgzentrum (BiK-F), Frankfurt am Main
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		Institut für Geologie und Mineralogie (Uni Köln), Köln
		Steinmann Institut für Geologie, Mineralogie und Paläontologie (Uni Bonn), Bonn
		Institut für Erdwissenschaften, Universität Graz, Graz
		Institut für Mineralogie (Uni Hannover), Hannover
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		Senckenberg Centre for Human Evolution and Palaeoenvironment (SHEP) , Frankfurt am Main
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		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
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		Institut für Geologie und Mineralogie (Uni Köln), Köln
		Institut für Geologie und Mineralogie (Uni Köln), Köln
		Max-Planck-Institut für Chemie (Mainz), Mainz
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Institut für Geowissenschaften (Uni Heidelberg), Heidelberg
		Institut für Geologie und Mineralogie (Uni Köln), Köln
		Institut für Erdwissenschaften, Universität Graz, Graz, Austria
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		Institut für Geowissenschaften (Uni Jena), Jena-Stadt
		Institut für Geologie und Mineralogie (Uni Köln), Köln
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		Zentrum für Marine Umweltwissenschaften (MARUM), Bremen
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		Institut für Geologie (Uni Hamburg), Hamburg
		Mikropäläontologie - Fachbereich Geowissenschaften (Uni Tübingen), Tübingen
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		Geowissenschaften (FB5 Uni Bremen), Bremen
		Independent Oil&Gas Consultant, Ratingen
		Institut für Mineralogie (Uni Hannover), Hannover
		Helmholtz-Zentrum für Ozeanforschung (GEOMAR), Kiel
		Deutsche Forschungsgemeinschaft (DFG), Bonn
		Institut für Geowissenschaften (Uni Heidelberg), Heidelberg
		Helmholtz-Zentrum für Ozeanforschung (GEOMAR), Kiel
		Angewandte Geophysik und geothermische Energie E.ON Energy Research Center (RWTH Aachen), Aachen Institut für Biochemie und Biologie (Uni Potsdam), Potsdam
		Geowissenschaften (FB5 Uni Bremen), Bremen
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		Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover
		Senckenberg Biodiversität und Klima Forschunsgzentrum (BiK-F), Frankfurt am Main
		Institut für Geographie und Geologie (Uni Greifswald), Greifswald
		Geowissenschaften (FB5 Uni Bremen), Bremen
		Institut für Geowissenschaften (Uni Frankfurt), Frankfurt am Main
		Institut für Geologie und Mineralogie (Uni Köln), Köln
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		Zentrum für Marine Umweltwissenschaften (MARUM), Bremen
		Institut für Geowissenschaften (IfG - Uni Kiel), Kiel
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		Zentrum für Marine Umweltwissenschaften (MARUM), Bremen
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Institut für Mineralogie (Uni Münster), Münster
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Leibniz-Institut für Angewandte Geophysik (LIAG), Hannover
		Leibniz-Institut für Angewandte Geophysik (LIAG), Hannover
		Zentrum für Marine Umweltwissenschaften (MARUM), Bremen
		Institut für Mineralogie (Uni Hannover), Hannover
		Zentrum für Marine Umweltwissenschaften (MARUM), Bremen
		Institut für Geographie und Geologie (Uni Würzburg), Würzburg

Fahrtberichte und Kurzfassungen – *Cruise Reports and Abstracts*

Fahrtberichte – *Cruise Reports*

AUTOREN *AUTHORS*	TITEL *TITLE*	SPP *PRIORITY PROGRAM*	SEITE *PAGE*
Philipp A. Brandl, Anna Kutovaya, Lucy Schlicht, Karen Strewlow, Chao Zhang, IODP Expedition 376 Scientists	IODP Expedition 376 Brothers Arc Flux	IODP	21
Oliver Esper, Juliane Müller, Oscar E. Romero	IODP Expedition 374: Ross Sea West Antarctic Ice Sheet History	IODP	22
Steffen Kutterolf, Matt J. Ikari, André Huepers, Expedition 372&375 scientists	Unlocking the secrets of slow slip by integrating core data, seismic and mechanical experiments, as well as borehole observatories at the offshore Hikurangi subduction zone, IODP Expeditions 372 & 375	IODP	23
Joana Seguin, Kostas Panagiotopoulos, Aleksandra Cvetkoska, A. Oflaz, D. Shillington , L. McNeill, Expedition 381 Scientists	IODP Expedition 381: Development of the active Corinth Rift	IODP	24

Kurzfassungen - Abstracts

AUTOREN *AUTHORS*	TITEL *TITLE*	SPP *PRIORITY PROGRAM*	SEITE *PAGE*
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IODP Expedition 376 Brothers Arc Flux

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Brothers is one of thirteen major volcanic centres of the active Kermadec arc front as part of the Tonga-Kermadec subduction system that extends from New Zealand to the islands of Tonga in the southwestern Pacific. Most of these arc volcanoes are magmatically and/or hydrothermally active making the Tonga-Kermadec system one of the most active arcs in the world. This, however, has not been recognised in the early days because most of the volcanoes are submarine and accessible by deep-sea research vessels only. Volcanic rocks along the Kermadec arc range in composition from basalt to rhyodacite. Their trace element and radiogenic isotope compositions indicate significant magma source heterogeneity both along and across the arc that results from variable subduction of continent-derived sediments, pelagic sediments and oceanic crust, and/or interaction with continental crust (e.g., Gamble et al., 1996; Haase et al., 2002; Timm et al., 2012). Furthermore, the shallower water depth of most hydrothermal arc systems as opposed to those at mid-ocean ridges, their high volatile flux with a direct magmatic contribution and their similarity to porphyry and epithermal deposits that – on land – are the main source of the metals our society is crucially depending on, make these systems highly relevant for science. Brothers with its 3.5 km wide caldera, a resurgent cone and its intense hydrothermal activity make this volcano an ideal target for the further understanding of hydrothermal arc systems. Several expeditions have studied Brothers volcano and confirmed

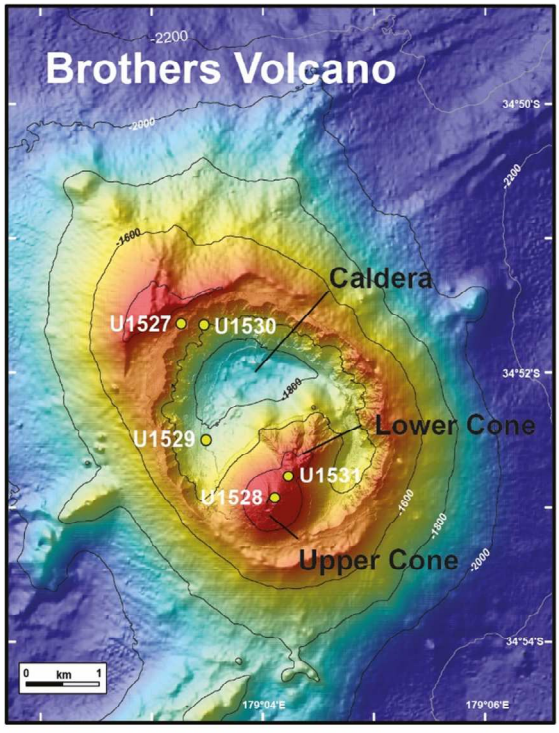

Figure. :1: Map of Brothers volcano with drill locations of IODP Exp. 376 (modified from Embley et al., 2012).

extensive high temperature venting at the NW caldera wall and on the resurgent domes. Two different types of hydrothermal venting are observed: a seawater-dominated system at the caldera wall and an epithermal-hydrothermal system at the resurgent cone. Magmatic volatiles are contributing directly to the latter system and the seafloor massive sulphide deposits at Brothers are known for their high Au contents (de Ronde et al., 2011). However, any understanding of these specific hydrothermal systems is hindered by the missing information from the subsurface and thus Brothers was identified as a prime location for deep drilling into an arc hydrothermal system.

In agreement with the specific challenges identified in the IODP Science Plan 2013-2023, the four primary scientific objectives outlined in the Expedition 376 Scientific Prospectus were to: A) characterize the sub-volcano, magma chamber-derived volatile phase to test model-based predictions that this is either a single-phase gas, or two-phase brine-vapor, B) determine the sub-seafloor distribution of base and precious metals and metalloids, and the reactions that have taken place along pathways to the seafloor, C) quantify the mechanisms and extent of fluid-rock interaction, and consequences for mass transfer of metals and metalloids into the ocean and the role of magmatically-derived carbon and sulphur species in mediating these fluxes, and D) assess the diversity, extent and metabolic pathways of microbial life in an extreme, metal-toxic and acidic volcanic environment (de Ronde et al., 2017).

The drill sites represent hydrothermal reaction zones of geochemically distinct fluids that are variably affected by magmatic volatile input, allowing us to directly address the consequences of magma degassing for metal transport to the seafloor and its effect on the functioning of microbial communities. Drilling conditions were often difficult: hole stability was affected by a significant cover of unconsolidated material, and high temperatures and acidity in the borehole were challenging for the equipment. Nonetheless and in parts due to the drilling-in of casing, IODP Expedition 376 successfully cored five, up to 450 m deep drillholes at Brothers volcano. With an average recovery rate of 18.1 %, 222 m of core were recovered, which is a significant improvement relative to previous attempts of drilling into hydrothermal systems (TAG, Pacmanus). During the expedition, a new turbine-driven coring system (TDCS) developed by CDEX was tested for the first time under real conditions.

Two sites were drilled into the northwestern caldera wall (U1527 and U1530), in order to drill into the seawater-dominated hydrothermal system. At Site U1527, we cored down to 238 mbsf and recovered two igneous units. Igneous Unit 1 – unconsolidated pyroclastic material made up of fragments of relatively unaltered, plagioclase-pyroxene-phyric dacite lava – overlies Igneous Unit 2. The latter is formed by hydrothermally altered volcaniclastic rocks, mostly lapilli-tuff and lapillistone, composed of altered dacite clasts embedded in a fine-grained altered matrix. Altered volcaniclastic rocks such as these were the most common lithology encountered during Expedition 376. The alteration mineralogy of the upper part of Site U1527 indicates seawater-rock interaction at low-temperatures < 150 °C (mainly goethite, opal CT, zeolites), while in the lower part the mineral assemblage changes to higher reaction temperatures ≤ 250 °C (chlorite, quartz, illite, pyrite). The general absence of veins and indications of late fracturing suggest that alteration at Site U1527 is not structurally controlled and may instead be due to pervasive flow. Some zones in the deeper part of the hole show possible evidence for crystal-plastic deformation in the form of white ribbons wrapped around larger volcanic clasts. Site U1530 is situated above a metal-rich stockwork zone. We cored down to 453 mbsf, recovering five igneous units. An altered lapillistone, forming Unit 1, overlies Unit 2, which is unique amongst lithologies recovered during Expedition 376. It is a sequence of altered tuffaceous mud-, silt- and sandstones that display various sedimentary textures such as grading and bedding. Sedimentary boundaries are all subhorizontal. Altered plagioclase-phyric dacite lava forms Igneous Unit 3, while Igneous Unit 4 consists of altered volcaniclastic rocks, mostly lapillistone and lapilli-tuff. Igneous Unit 5 is altered volcanic rock (more detailed classification was hindered by intense alteration) with a few intercalated less altered plagioclase-phyric lavas. Volcanic fabrics are defined by aligned vesicles and/or microlites and occur within clasts (not sharing a common orientation) and over larger scales in coherent lavas, where they tend to show dips >45°. The alteration in the upper part of Site U1530 corresponds to the low-temperature mineral assemblage already found in the upper part of the other drilling site at the NW Caldera U1527. At Site U1530, the low-temperature zone is again first followed by alteration minerals pointing to higher reaction temperatures with seawater (mainly quartz, illite, chlorite), but in the deeper parts a mineral assemblage typical for reaction with acid-sulphate fluids follows (dominantly diaspore, quartz, pyrophyllite). In the deepest parts, the pyrophyllite-rich mineral assemblage is locally intercalated with chlorite-rich layers. Veins occur throughout the hole at Site U1530 and

are typically filled with anhydrite, silica, and/or pyrite. Vein density is variable downhole, with the highest density related to the presence of network veins, typically filled with pyrite or silica. Downhole logging was performed at Site U1530 with a high-temperature flasked wireline logging string consisting of lithodensity, NGR, and logging head temperature tools, revealing a temperature profile that is indicative of a largely conductive-dominated regime in the borehole.

Site U1528 is located inside the pit crater at the summit of the Upper Cone of Brothers volcano, within the upflow zone of a hydrothermal system strongly influenced by magmatic degassing. We cored down to 359 mbsf and recovered three igneous units. The crater is covered with a polymict lapilli tephra, consisting of variously altered volcanic clasts and native sulphur. This unit overlies Igneous Unit 2, composed of hydrothermally altered volcaniclastic rocks, mostly lapillistone and lapilli-tuff, and one intercalated less altered dacite lava. Igneous Unit 3 is formed by altered dacite lava. Volcanic fabrics occur within volcanic clasts, where they do not share a common orientation suggesting brecciation after fabric formation. In coherent lavas, volcanic fabrics tend to dip >45°. The alteration is represented by a complex interplay between secondary minerals like illite, pyrophyllite, natroalunite, quartz, pyrite and native sulphur with three main alteration styles. The occurrence of minerals like pyrophyllite, natroalunite and native sulphur points to interaction with acid-sulphate fluids, potentially derived from magmatic fluid influx. Alteration veins occur throughout and are most commonly filled by anhydrite, pyrite, silica, and native sulphur. Fluids were sampled at different depths and at temperatures between 140 and >236°C. H_2S odour emitted from the core is associated with zones of lower bulk density/higher porosity, a borehole temperature anomaly, increased fracture density, vein thickness and range of vein dip.

Hole conditions at Sites U1529 and 1531, located on the western side of the caldera floor and on the saddle between the two volcanic cones, respectively, were very difficult. Unconsolidated pyroclastic material made the hole unstable and clogged the drilling equipment, such that boreholes were abandoned after reaching a maximum coring depth of just 34 mbsf and 40 mbsf, respectively. The pyroclastic material at both sites is made up of relatively unaltered, plagioclase-pyroxene-phyric dacite lavas intercalated with ash- to lapilli-sized fragments of the same dacite. Volcanic fabrics are defined by elongated vesicles, phenocrysts and microlites. At U1531, these fabrics have moderate to steep dips. The detection of relatively high concentrations of H_2 and acid-volatile sulphides in some intervals at U1531 is consistent with discharging magmatic gases through the volcanic pile at the cones of Brothers volcano. The unaltered dacite lavas found at Sites U1527, U1529 and U1531 are geochemically and petrographically similar to each other and to those previously collected on the seafloor at Brothers volcano, consistent with the small compositional range reported for dacites at this volcano. Despite the pervasive alteration of altered volcaniclastic and volcanic rocks at Sites U1527, U1528 and U1530, residual magmatic textures and the concentration of alteration-resistant elements suggest that the protolith for altered volcanic rocks at these sites also were typical Brothers dacites.

More than 40 whole-round samples were collected in total (from all Sites except U1529) for microbiological analysis. Samples were processed for shore-based DNA and RNA analyses, cell and viral counting, and viral and microbial activity measurements. Quantification of the contamination tracer perfluoromethyldecalin (PFMD) was conducted for the drilling fluid and the exterior and interior parts of whole-round samples. PFMD was routinely detected, although barely above detection levels, suggesting that contamination by drilling fluids of the interior of whole-round samples was minimal.

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IODP

IODP Expedition 374: Ross Sea West Antarctic Ice Sheet History

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Ice shelf thinning and accelerated mass loss of the West Antarctic Ice Sheet (WAIS) are currently leading to a retreat of the marine-based WAIS. This retreat is linked to a shift in wind-driven oceanic currents transporting warm waters toward the ice margin. Climate models strengthen a fundamental role for oceanic heat in controlling the significant variability in marine-based ice sheet extent during the late Neogene and Quaternary. While sediment cores obtained from Antarctica's proximal shelf areas provide evidence for past ice sheet advances and retreats, additional data from the outer continental shelf is needed to determine the extent of past ice sheet variability and associated oceanic feedback mechanisms.

International Ocean Discovery Program Expedition 374 drilled a latitudinal and depth transect from the outer to the inner continental shelf in the Ross Sea (Fig. 1). Sediments obtained from five drill sites will help to resolve the relationship between climatic and oceanic change and WAIS evolution through the Neogene and Quaternary. The Ross Sea is an ideal target area as this sector of Antarctica is highly sensitive to changes in ocean heat flux. A main objective of the expedition was to integrate model and sediment data, which will improve our understanding of the sensitivity of Antarctic Ice Sheet (AIS) mass balance during warmer-than-present climates (e.g., the Pleistocene "super interglacials," the mid-Pliocene, and the late early to middle Miocene).

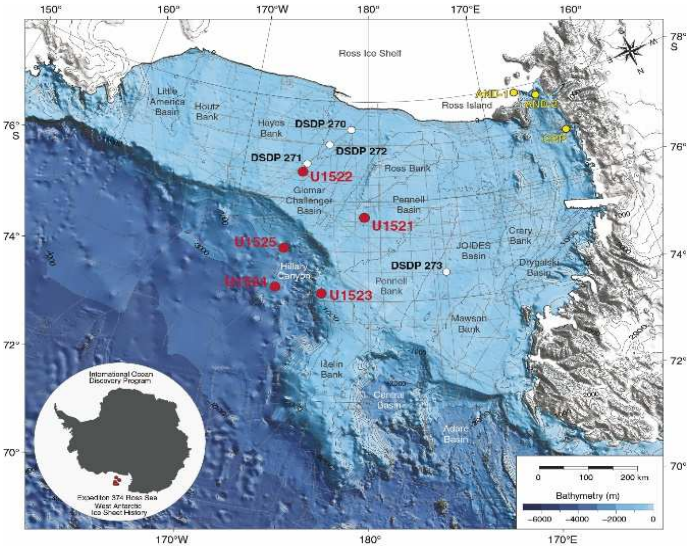

*Figure 1: Bathymetric map with **Expedition 374** sites and previous Deep Sea Drilling Project (DSDP) Leg 28, Antarctic Geological Drilling Project (AND), and Cape Roberts Project (CRP) sites. Ross Sea bathymetry is from the International Bathymetric Chart of the Southern Ocean (Arndt et al., 2013). Existing seismic network is from the Antarctic Seismic Data Library System and includes some single-channel seismic profiles.*

Major goals of Expedition 374 were to (1) evaluate the contribution of West Antarctica to far-field ice volume and sea level estimates; (2) reconstruct ice-proximal atmospheric and oceanic temperatures to identify past polar amplification and assess its forcing and feedbacks; (3) assess the role of oceanic forcing on AIS stability/instability; (4) identify the sensitivity of the AIS to Earth's orbital configuration under a variety of climate boundary conditions; and (5) reconstruct eastern Ross Sea paleobathymetry to examine relationships between seafloor geometry, ice sheet stability/instability, and

global climate.

To achieve these objectives, it is intended to (1) use data and models to reconcile intervals of maximum Neogene and Quaternary Antarctic ice advance with far-field records of eustatic sea level change; (2) reconstruct past changes in oceanic and atmospheric temperatures using a multiproxy approach; (3) reconstruct Neogene and Quaternary sea ice margin fluctuations in datable marine continental slope and rise records and correlate these records to existing inner continental shelf records; (4) examine relationships among WAIS stability/instability,

Earth's orbital configuration, oceanic temperature and circulation, and atmospheric pCO_2; and constrain the timing of Ross Sea continental shelf overdeepening and assess its impact on Neogene and Quaternary ice dynamics.

Expedition 374 recovered 1292.70 m of high-quality sediment cores from five sites covering the early Miocene to late Quaternary (Fig. 1). Sites U1521, U1522, and U1523 were cored on the continental shelf.

A 650-m thick sequence of interbedded diamictite, mudstone, and diatomite, penetrating the Ross Sea Seismic Unconformity RSU4 was obtained at Site U1521. Reconstructions of past glacial and open-marine conditions at this site will give insight into environmental changes on the Antarctic continental shelf during the early and mid-Miocene.

At Site U1522, a discontinuous sequence of glacial and glaciomarine strata of upper Miocene to Pleistocene age was recovered from the outer shelf, with the primary objective to penetrate and date Seismic Unconformity RSU3, which is interpreted to represent the first major continental shelf–wide expansion and coalescing of marine-based ice streams from both East and West Antarctica.

A sediment drift located beneath the westerly flowing Antarctic Slope Current (ASC) was cored at Site U1523. Sediments from this site will provide a record of the changing vigor of the ASC through time, which allows testing the hypothesis that changes in the vigor of the ASC represent a key control on regulating heat flux onto the continental shelf and hence affecting ice sheet mass balance.

Sites U1524 and U1525 were cored on the Ross Sea continental slope and rise. At Site U1524, a Plio–Pleistocene sedimentary sequence was obtained on the levee of the Hillary Canyon (Fig. 1), which is one of the largest conduits of Antarctic Bottom Water delivery from the Antarctic continental shelf into the abyssal ocean. Drifting sea ice forced us to abandon coring in Hole U1524A at 399.5 m drilling depth below seafloor and prevented the recovery of mid Miocene and older strata. We moved to a nearby alternate site on the continental slope (U1525) to core a single hole with a record complementary to the upper part of the section recovered at Site U1524. After the sea ice has cleared, we returned to Site U1524 and cored Hole U1524C with the intention of reaching the target depth of 1000 m DSF. However, coring Hole U1524C had to be terminated at 441.9 m DSF due to a mechanical failure with the vessel that resulted in termination of all drilling operations and a return to Lyttelton 16 days earlier than scheduled. With the loss of 39 % of operational days, the deeper time record of the mid Miocene on the continental rise and abyssal sequences that would have provided a continuous and complementary archive to the high-quality (but discontinuous) record from Site U1521 on the continental shelf could not be recovered. Due to the mechanical failure, no sediment cores from proposed Site RSCR-19A were obtained, which was targeted to provide a continuous record of upper Neogene and Quaternary pelagic/hemipelagic sedimentation. Despite the failure to recover a shelf-to-rise transect for the Miocene, a continental shelf-to-rise transect for the Pliocene to Pleistocene interval is possible through comparison of the high-quality records from Site U1522 with those from Site U1525 and legacy cores from the Antarctic Geological Drilling Project (ANDRILL).

IODP

Unlocking the secrets of slow slip by integrating core data, seismic and mechanical experiments, as well as borehole observatories at the offshore Hikurangi subduction zone, IODP Expeditions 372 & 375

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The overarching aim of IODP Expeditions 372 and 375 were to assess the causes and impacts of slow slip events (SSEs). SSEs, are events in which slip occurs faster than the plate convergence rate but too slowly to produce seismic waves. The Hikurangi subduction margin, offshore the northern East coast New Zealand, is the location of some of the world's best-documented SSEs. They may have the potential to trigger highly destructive earthquakes and tsunami on faults nearby, but whether this is possible and why slow slip events occur at all are two of the most important questions in earthquake research today. Most well-studied SSEs (e.g. in Cascadia and SW Japan) occur at depths exceeding 20 km, too deep for direct sampling and high-resolution seismic imaging. A notable exception to this is the north Hikurangi margin, New Zealand. Seafloor geodetic studies revealed that SSEs here occur every 1-2 years, over periods of 2-3 weeks within at least 2 km of the seafloor with the possibility that they propagate all the way to the trench. Therefore, the large magnitude and close proximity of the SSEs to the seafloor makes it feasible at the Hikurangi margin to precisely locate, drill into, collect logs, sample, image and recover physical property information from 3D seismic and conduct near-surface monitoring of the area of the fault undergoing slow slip. In Nov-Dec 2017 and March-May 2018 two International Ocean Discovery Program (IODP) expeditions, 372 and 375, used scientific drilling in New Zealand for the first time to target those slow slip events (Figure 1).

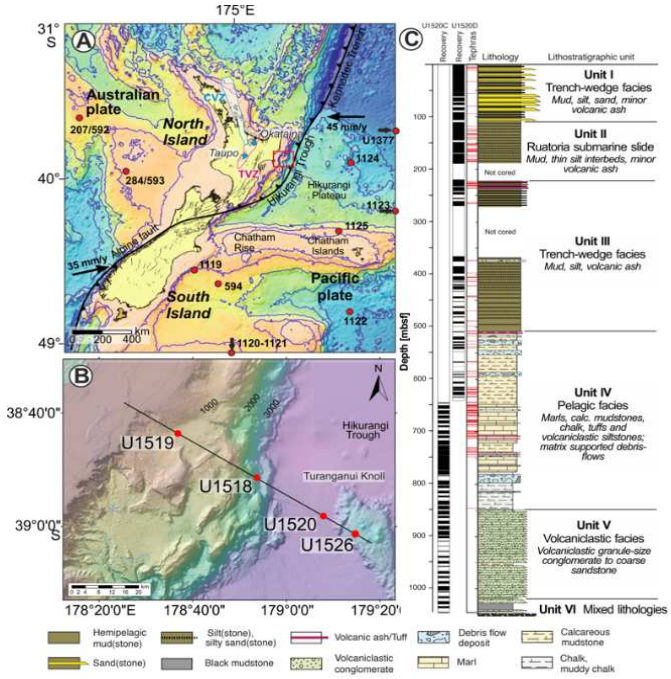

Figure 1: A) Tectonic setting and overview of New Zealand after Saffer et al. (2018), indicating older DSDP, ODP and IODP sites (black dots Exp. 330, 181, 90, 29, and 21 sites) as well as the location of the TVZ (magenta line, after et al. Wilson 1995) and CVZ (blue line, after Hopkins and Seward 2019); B) Bathymetry and location of seismic Line 05CM-04 (black line) in the region of Expedition 375 near Gisborn modified after Saffer et al. (2018), red Dots = Exp.375 sites; C) stratigraphic and lithological section for U1520 drilled during Exp. 375.

The expeditions documented the lithology and the physical, hydrogeological and chemical properties of the active frontal thrust region and associated slope overlying the SSE source region, as well as the inputs of sediment and upper igneous crust of the subducting Pacific Plate that will eventually host SSEs (Pecher et al. 2018, Saffer et al. 2018). IODP Expedition 375 additionally completed installation of two subseafloor observatories at the offshore Hikurangi margin - one that intersects a major active fault near the deformation front and another one above the slow slip area - to monitor deformation, temperature, hydrogeology, and seismicity related to slow slip event processes over the next years (Saffer et al. 2018).

IODP Expedition 372 cored one site (U1517) at ~720 m water depth at the slope of the Hikurangi Margin, east of the coast of New Zealand to investigate the large submarine Tuaheni Landslide. They recovered a 189 meters thick sequence of clayey silt with sandy intervals (Pecher et al. 2018)

that also contain several felsic tephra horizons. In addition to this site, IODP expedition 375 cored a further 12 holes at four sites (U1518, U1519, U1520, U1526) with a total recovery of ~1160 meters of sediment reaching back to the Cretaceous (e.g. Figure 2, Saffer et al. 2018). One major target for the research expeditions was to compositionally characterize the sediments and their temporal occurrence within the successions of the upper- and subducting-plates of Hikurangi margin. Especially this cored material is also in focus of the three participants from German IODP and planned shore-based projects are outlined briefly below.

Figure 2: Condensed section from U1526A covering the Pliocene (to the right) to Late Creteacous sedimentation on top of Tūranganui Knoll

In addition to the predominant silty clay(stone) or mud(stone) encountered, preliminary shipboard observations also identified numerous tephra horizons (~330 in total) distributed episodically throughout the sediment succession of all cored sites covering the Quaternary and Neogene (Saffer et al. 2018). A key to investigate the timing of these events is to establish a detailed chronostratigraphy and, next to paleomagnetic and biostratigraphic ages, the ages of tephra layers are critically important to better constrain this chronostratigraphic framework. Dating of the tephra layers is done either by correlations to well-dated on-shore deposits (e.g. through geochemical fingerprinting) or by direct age dating (e.g., through radiometric techniques). The discrete marine tephra horizons (and to some extent the more disperse tephras within the sediments), provide a unique archive and important marker horizons to date the sediments. In addition, reconstructing these eruption histories post-cruise allow the abundance and provenance of explosive eruptive history of New Zealand to at least the Miocene to be deciphered.

The incoming sedimentary sequence is also representative of the shallow fault material where SEEs events will take place once they enter the subduction zone. These sediments were sampled during IODP Expedition 375 and will be used in laboratory experiments to test which rock types are most likely to host these events and to characterize their frictional behavior. Experiments are performed on both intact and powdered rock samples from the major lithologies entering the subduction zone. One particular testing procedure includes shearing at different speeds to simulate shallow slow slip at the Hikurangi margin and relaxation in between (~160 cm/year), and subsequent modeling of the frictional changes. A combination of previous work on Hikurangi sediments and first preliminary results suggest that the velocity-weakening behavior in the overlying sediments could allow slip to propagate along faults up to the seafloor. Ongoing work includes characterization of the frictional behavior of the heterogeneous lowermost unit, measuring the roughness of the sheared fault surfaces to explore a possible connection between roughness and friction or slow slip parameters, and microstructural analyses of the sheared samples to identify the possible mechanisms responsible for producing SSEs.

Drill sites at the frontal thrust and on the upper plate target fault zones provide a window to the slow slip source region. Identification and spatio-temporal characterization of important diagenetic processes and their influence on the hydro-mechanical state of the subduction thrust through diagenesis, clay dehydration processes and fluid migration are expected to play an important role for the occurrence of SSEs. A coordinated strategy of fluid and whole rock geochemistry in combination with boron and lithium isotope analysis will be implemented to constrain diagenetic driven water-rock interaction processes. Those analysis will be complemented with hydrothermal compaction tests to improve identification of geochemical fingerprints of fluid-rock processes. Integration of the geochemical data with reaction-transport models will predict qualitative and quantitative observations in space and time in the subduction zone forearc.

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IODP

IODP Expedition 381: Development of the active Corinth Rift

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International Ocean Discovery Program Expedition 381 was operated as a Mission Specific Platform onboard the industry drilling vessel Fugro Synergy between October and December 2017 in the Gulf of Corinth, Greece. The onshore phase took place in Bremen, Germany in February 2018. The drilling sites (M0078, M0079 and M0080) are located across the Gulf of Corinth within an active continental rift zone (Figure 1). A total of 1645 m of sediments were retrieved along the rift with an average recovery of 85%. The absence of volcanism and the exceptionally high extension rates of the rift allow for detailed fault and sedimentary basin development reconstructions without the complications of later over printing.

The primary objectives of the expedition were to target a very recently forming active continental rift zone in order to: (1) obtain high spatial and temporal resolution records of the dynamics of the rifting process and its evolution, (2) study the interaction of climate and tectonics on sedimentary and surface processes in a rift zone, (3) generate a new high resolution record of Quaternary paleoclimate and paleoenvironment evolution (aquatic and terrestrial) from a semi-isolated basin dominated at present by typical Mediterranean ecosystems, and (4) to improve regional hazard assessments in one of the most seismically active regions of Europe.

Preliminary results produced during the onshore phase indicate that the cores hold a unique and detailed record of how tectonics, climate and paleoenvironment have affected syn-rift basinal deposition. The rift basin is periodically closed from marine conditions as sea level fluctuates (glacial-interglacial cycles) and as the rift moves vertically due to tectonics. Therefore, a unique range of paleoenvironmental gradients is encountered across the central (M0078 and M0079 in the Gulf of Corinth) and eastern (M0080 in the Alkyonides Gulf) rift impacting depositional processes, sediment chemistry and composition of microfossil assemblages such as marine calcareous nanofossils as well as marine and terrestrial palynomophs (Shillington et al., 2019; McNeill et al., 2019; in review).

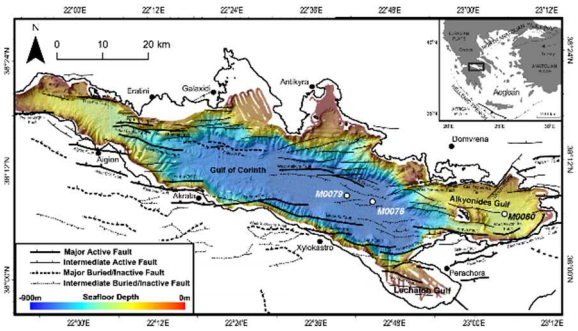

Figure 1: Bathymetric map showing the locations of the three sites drilled during the IODP Expedition 381. Sites M0078 and M0079 are located in the central basin, while site M0080 is in the east in the Alkyonides Gulf. (Shillington et al., 2019; McNeill et al., 2019)

A dense network of marine seismic data and well-studied onshore syn-rift deposits provide the potential to extend the drilling results around the entire rift system. These new insights into how the earliest phase of rifting takes place and impacts the depositional environment are expected to make significant advances that can be used to understand other active and ancient rifts around the world. In addition, the relatively isolated basin located in southern tip of the NE Europe is a key region for understanding the evolution of Quaternary marine and terrestrial ecosystems in the Mediterranean.

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Kurzfassungen - Abstracts

ICDP

Present and past microbial signatures in deep sediments of the Hartoušov CO2 mofette system, NW Bohemia

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A mofette is a natural cold, dry or wet gas vent releasing CO_2-rich gases into the atmosphere. The Hartoušov mofette system is located in the northern Cheb Basin (western Eger Rift, Czech Republic). The area is characterized by mantle-derived gas emanations (> 99 % CO_2) since the early Pleistocene (Bankwitz et al., 2003). The gas preferentially migrates either dissolved in water or as a free gas phase along deep-seated faults to the surface (Bräuer et al., 2008). Previous studies of surface near sediments of Holocene and Pleistocene age at Hartoušov showed that ascending CO_2-containing fluids result in significant lithological and microbiological community changes (Flechsig et al., 2008; Beulig et al., 2015; Liu et al., 2018). Deeper microbial habitats may be indicated by the presumed presence of underlying CO_2-containing fluid trap structures in crustal and sedimentary rocks releasing increased amounts of gas after seismic events to the surface (Fischer et al., 2017). Nickschick et al. (2015) described the presence of dm- to m-sized cavities in sediments of the open-cast mine Nová Ves II at 50 m depth which occur along ascending fluid pathways suggesting potential habitats for CO_2-related deep microbial life. An increase in methane concentrations at the Wettinquelle (Bad Brambach) with a microbial $\delta^{13}C$ signature after swarm earthquakes in 2000 was interpreted as enhanced microbial activity stimulated by seismically mobilized CO_2 and released hydrogen from granitic basement rocks (Bräuer et al., 2005). In summary, there are indications for subsurface CO_2-influenced habitats which could act as hotspots for deep microbial life. However, studies investigating such microbial habitats are still missing for deep mofette systems. In spring 2016 a pilot borehole was drilled by GFZ Potsdam for the PIER-ICDP study "Drilling the Eger Rift" (DFG Alawi, AL 1898/1) into the Hartoušov mofette system. During drilling a CO_2 blow-out occurred in about 78 m depth, suggesting a CO_2 reservoir in sediments of Early Miocene age (Bussert et al, 2017). In consequence, samples from above, within and below this interval were selected to test whether this interval could host a specific habitat stimulating a deep CO_2-related microbial ecosystem.

Here, we present results about past microbial ecosystems and their depositional environment. Conceptually, sedimentological bulk parameters and lipid biomarker signals (n-alkanes, sterenes, hopanoids and glycerol dialkyl glycerol tetraethers GDGTs) are compared with signals of present microbial communities. Such present signals include microbial life marker lipids (intact membrane lipids) and data gained by microbiological analyses such as quantitative PCR and Illumina $_{16}S$ rRNA gene amplicon sequencing (Liu et al., unpubl. data).

The Miocene depositional environment is characterized by a change from a terrestrial to a lacustrine setting. Increased abundance of past microbial communities in the terrestrial sediments are related to phases of soil or peat formation. The abundance and compound specific carbon isotopic composition of the past microbial markers mainly reflect these palaeo-environmental changes. Such biomarkers reflect activity of heterotrophic bacteria, of soil bacteria in the terrestrial sediments, and methanogenic archaea and presumably methane oxidizing bacteria in the lacustrine sediments. The transition from the terrestrial to the lacustrine depositional environment marks the detected interval of increased CO_2 concentrations at 78 m depth. In contrast to the past microbial signals, microbial life marker lipids were rarely found in the CO_2 reservoir. Phospholipid fatty acids from living bacteria are essentially absent. However, some yet unknow intact lipid signals indicating living bacterial biomass were detected, and compound identification is currently underway.

In summary, although there are indications for a deep microbial ecosystem in the CO_2 reservoir interval of the Hartoušov mofette system, this interval seems not to represent a hotspot for deep microbial life.

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IODP

Shallow subduction zone serpentinization traps fluid-mobile elements: implications for element mobilization from serpentinite mud volcanism (IODP Exp. 366)

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Serpentinite mud volcanism at the forearc of the Mariana subduction zone provide a window into an active subduction system. Trace elemental inventories of upwelling slab-derived fluids and serpentinized mantle wedge materials reflect processes significant for the understanding of fluid–rock interactions and related mass transfers in subduction zones. To elucidate the mobilization of fluid-mobile elements (FMEs) at forearc depths, we investigated variably serpentinized ultramafic clasts from Yinazao, Fantangisña, and Asùt Tesoru serpentinite mud volcanoes recovered on IODP Exp. 366. These mud volcanoes sample the slab–wedge interface at depths of ~13 to 18 km and temperatures of ~80 to 250°C. The samples originate from the basal plane of the mantle wedge and exhibit a multi-phase serpentinization history, as apparent from microfabrics, mineralogy, and in situ major and trace elemental analyses in distinct serpentine generations. Initial hydration occurred under reducing conditions by Si-rich fluids. Serpentine is characterized by generally high concentrations of Li, B, Sr, Rb, Cs, and Ba. Subsequent interactions with Si- and FME-poor fluids occurred in the serpentinite mud volcano conduits and resulted in the abundant presence of Fe-rich brucite. Oxic conditions prevailed during alteration of the clasts at the seafloor. Variations of FMEs in serpentine, being a function of slab depth, allowed us to reconstruct FME and fluid sources. Serpentine from the shallow-sourced Yinazao exhibits high Rb/Cs ratios, highest concentrations of Li and B, but lowest Rb, Sr, Ba, and Cs contents. Serpentinization fluids were influenced by pore waters and the breakdown of opal in the subducted sediments. Serpentine at intermediate-sourced Fantangisña has lower Rb/Cs ratios, and lower B and higher Rb and Cs contents as Yinazao. These represent the H_2O- and FME-release from clays in the subducting sediments. Fluids at deep-sourced Asùt Tesoru as well originate from clay breakdown but highest concentrations of Rb, Sr, Cs, and Ba are further indicative of beginning dehydration of altered oceanic crust. Including data from South Chamorro serpentinite mud volcano (18 km slab depth; Kahl et al., 2015, Lithos), we provide a continuous record of slab dehydration reactions at forearc depths and the related mobilization of FMEs as well as their transport into the mantle wedge. Some of the FMEs contained in serpentinite are transported back to the seafloor in the Mariana subduction zone, they will remain at depth in most other active continental margins.

ICDP

Paleomagnetic and palynological investigations of a new Plio-Pleistocene drill core from paleolake Idaho (Northwestern United States)

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An ICDP drilling campaign carried out in 2011 has recovered 536 m of sediment cores from paleolake Idaho in the western Snake River Plain, northwestern United States (Shervais et al. 2013). The drillcores consist of fine-grained lacustrine sediments of late Pliocene and Pleistocene age, thereby yielding a promising paleoclimate archive that covers the warm late Pliocene, the Plio-Pleistocene transition as well as the onset of the Northern Hemispheric glaciations. This is the first record from continental North America covering this time interval at one site.

An indispensable prerequisite for the exploitation of this high-potential paleoclimate archive is the establishment of high-quality age control. Therefore, we have carried out paleomagnetic analyses of the Mountain Home drill core (MHAFB11), which has been drilled close to the center of former paleolake Idaho. Stepwise thermal and alternating field demagnetization revealed an inclination pattern based on the characteristic remanence magnetization (ChRM) directions. The demagnetization behavior revealed a single-component ChRM with reverse and normal polarities in the lower and upper parts of the succession, respectively. A ~70 m interval in between shows a two-component dual-polarity behavior that cannot be explained with lock-in depth effects. We assume a secondary overprint by chemical remanent magnetization (CRM) due to alteration processes such as partial remineralization of magnetite and maghemite that affected a wide depth range below the corresponding level. Based on rock-magnetic measurements we interpret the reverse polarity component as a CRM and locate the polarity change from normal to reverse at 568 m core depth. Based on age constraints from Ar/Ar dating, this reversal represents the Gauss/Matuyama boundary. Its identification yields an important new age constraint for the MHAFB11 core.

As a first step in the paleoclimatic evaluation of the MHAFB11 core, we have palynologically analyzed 80 samples from the 732–439 m depth interval (corresponding to an approximate age of 3.5–2 Ma based on the yet available age control). This preliminary dataset, which has a mean temporal resolution of c. 19 ka, documents that a Pinus-dominated coniferous forest biome prevailed in the catchment area of paleolake Idaho. Findings of Juniperus-type pollen taxa document the presence of *Cupressaceae*, either through Juniperus that thrived in relatively dry settings within the catchment area or, more likely, through the swamp cypress Taxodium that grew along the shores of the lake. In the younger part of the succession, pollen representing steppe vegetation (e.g., *Artemisia, Asteraceae*) becomes increasingly abundant, whereas the percentages of conifer pollen decrease. This transition represents a trend towards cooler/drier conditions. Further upsection, pollen from deciduous trees (particularly *Quercus robur-type* and *Alnus*) occurs, reaching abundances of up to 5 %. We interpret this spread to be due to more temperate conditions.

Pending further refinement of the age/depth relationship of the MHAFB11 core, future palynological work will yield detailed insight into the paleoenvironmental and paleoclimatic evolution in northwestern North America during the late Pliocene and Pleistocene. As such, it will contribute to a better understanding of the Plio-Pleistocene world, including climatic change connected to the initiation of larger-scale glaciations in the Northern Hemisphere at c. 2.7 Ma.

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ICDP

Antarctic Ice Sheet and carbon cycle dynamics at the late Eocene to early Oligocene

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The Antarctic Ice Sheet (AIS) first grew during the Eocene-Oligocene transition (EOT) primarily in two steps, with the first likely characterised mostly by cooling (~ 34 Ma) and the second with ice growth (~33.5 Ma). Although ice proximal drilling largely supports this view, recent studies suggest that there was considerable variability in advances and retreats of continental-based AIS during this interval, which is also evident in a number of benthic and planktonic $\delta^{18}O$ records and sea level estimates, and spatial heterogeneity in seawater sea surface cooling. Low resolution records of atmospheric CO_2 from boron isotope and alkenone based proxies during this interval both support a decline in CO_2 from ~1000 ppm to ~700 ppm, suggesting a primary role of CO_2 in driving this transition. It is also evident that CO_2 rebounded to pre-EOT values at the time when AIS retreated and ice volume was reduced. Given that atmospheric CO_2 has not been this high since the early Oligocene, and its central role for the Oi1 glaciation, the late Eocene to early Oligocene period offers a unique opportunity to constrain the hypothesis of a threshold CO_2 concentration for the response of AIS to climate, and underlying carbon cycle dynamics.

IODP

The HimalFan project – The Quantification of Himalayan Erosion Fluxes from the Bengal Fan record based on seismic stratigraphy and geochemical analyses

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Submarine fans store continental sediments and thereby act as a fundamental archive for the conti-nental tectonic and erosion history as well as long- and short-term climate variations. The Bengal Fan is a submarine fan of particular scientific importance. It is the primary record for southern Asia, where the high elevation of the Tibetan Plateau and the Himalayan Mountain range affect both the temperature structure of the atmosphere and the localization of the Asian Monsoon precipitation (Molnar et al., 2010; Boos & Kuang, 2011). Precipitation along the Himalaya generates a significant erosional flux and thereby participates in the global drawdown of atmospheric CO_2 through organic carbon burial and silicate weathering (France-Lanord and Derry, 1997).

In 2015, the Bengal Fan has been target of IODP Expedition 354 during which a seven-site west-east transect at the lower Bengal Fan (8°N) has been drilled (France-Lanord et al., 2016). Integration of the IODP Expedition 354 drilling results with an extensive dataset of high-resolution multichannel seismics across the Bengal Fan allowed us to investigate spatial and temporal variability of sediment delivery and depositional processes since the Middle Pleistocene.

The investigations revealed that sedimentation is organized in subfans governing only parts of the Bengal Fan while hemipelagic deposition dominates simultaneously in the remaining fan area. Guided by topographic highs created by the 85°E Ridge and Ninetyeast Ridge, the location of the subfans alternates between the western and the eastern fan on timesclaes of ~200-500 ka. Moreover, a 2D analyses of the contribution of different sediment types revealed an unexpectedly high sand content of ~44%. Finally, a channel-levee stacking pattern has been developed thereby enabling the compar-ison and correlation of the seven IODP Expedition 354 drill sites on a relative stratigraphy.

Building on IODP Expedition 354 and the seismic stratigraphy the recently started ANR-DFG joint French-German project 'HimalFan' (Quantifying Himalayan Erosion Fluxes from the Bengal Fan record) has been developed. The HimalFan project is based on a multidisciplinary approach

aiming at further improving our understanding of the Himalayan tectonic construction and its coupling with regional and global climate. 2D and 3D seismic analysis will be conducted at Bremen University focusing on the establishment of a stratigraphic synthesis, the determination of fan growth rates, the reconstruction of the Neogene evolution of thickness trends in response to quality and quantity of delivered sediments, and the sand transport to the fan including a quantification of sand content utilizing seismic attributes to finally assign the controls on Bengal Basin evolution in general.

The HimalFan project further involves single grain thermochronology and quartz in situ cosmogenic analyses to reconstruct erosion rates, geochemical tracers and mineralogy to relate erosion to struc-tural evolution on the source area, and the evaluation of C fluxes. These analyses are conducted at the two French partner institutes CRPG (Nancy) and IsTerre (Grenoble) in order to quantify the Him-alayan erosion and deposition fluxes at different time scales and analyse the response of erosion to tectonic and climate changes. Synthesizing the variable approaches of the HimalFan project will eventually be used to decipher the timing and impact of the tectonic evolution of the Himalayan Mountain range, the Bengal Basin evolution, sediment transport processes, and the link between climate and erosion.

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ICDP

PRO-HYDRO: Sediment provenance and past hydrological balance in the Dead-Sea region during the Early Holocene

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As being a climatic cross-point between North Atlantic-driven winter precipitation and southern monsoonal systems, the Levant is an ideal location to study environmental responses to past climatic changes. It has also proven itself a key region for human population dynamics, acting as a migration corridor and a cradle for prehistoric populations. Recovered in 2011, the continuous sediment record of ICDP Dead Sea Deep Drilling Program Site 5017-1 provided a unique insight into past hydrological changes that resulted in large lake-level fluctuations.

With the PRO-HYDRO project, we aim at investigating past precipitation regimes that controlled the erosion dynamics in the Dead-Sea watershed during the early Holocene. This time interval is a key period encompassing both orbital-forced and rapid climatic changes. We will use tracers of sediment provenance such as neodymium (Nd) and strontium (Sr) radiogenic isotopes of specific lithogenic grain-size fractions to trace the sources of fluvial input. Together with ICDP Site 5017-1, we will use sediment archives from Ein Feshkha and Ein Gedi located on the western Dead-Sea margin. A recent field campaign in Jordan also permitted to sample surface sediments that will be used in conjunction with existing datasets and other recently sampled locations to obtain a complete coverage of the Dead-Sea drainage basin and calibrate our study. Promising sites with undisturbed and laminated sediment sequences were discovered on the eastern Dead-Sea shore, that can provide additional insights into sediment and climate dynamics during the Holocene. By building detailed chronologies using varve counting, tephrochronology and radiocarbon dating, these early Holocene records will allow comparisons to other climatic archives within and beyond the Levant.

IODP

Pore fluid - seawater exchange of rare earth elements in the Labrador Sea since the Last Glacial

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The Labrador Sea has been shown to be a location where intense exchange of rare earth elements (REE) between seawater and sediments takes place [1]. Such boundary exchange near ocean margins represents an important mechanism that modifies the isotopic signatures of Nd dissolved in ocean bottom water masses around the world [2]. The exact processes controlling boundary exchange or benthic fluxes of REE out of sediments into bottom waters are not well understood, yet they appear to take place dominantly in shallow sediment pore fluids under as yet unresolved conditions [3,4]. At present, essentially no information on potential changes of these processes is available on glacial-interglacial time scales.

Here we develop a new conceptual model of REE exchange between sediments and bottom waters via pore fluids based on existing observations and hypotheses [3]. We reassess existing estimations of Nd exchange fluxes in the Labrador Sea based on recently published new seawater measurements and application of the pore fluid exchange model. In a second step, we employ authigenic Nd isotope records from two sites in the Labrador Sea in order to estimate past benthic fluxes of Nd, as well as bottom water Nd concentrations and isotopic signatures since the Last Glacial Maximum.

The results are in agreement with an independent adjustment of the same sediment Nd isotope data and reveal significant fluctuations of benthic Nd fluxes into bottom waters, in particular during the early Holocene. Based on the model results, the resulting Nd isotope signatures of Labrador Sea bottom waters could have been up to 5 epsilon units less radiogenic than today, while dissolved Nd concentrations may have been increased by up to a factor of 2.

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IODP

Indian Monsoon induced erosion during the Miocene recorded at IODP Site U1443 (Exp. 353)

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IODP Site U1443 recovered a complete sequence of Oligocene to recent hemi-pelagic/pelagic sediments in the southern Bay of Bengal on the northern tip of the Ninetyeast ridge. We are using this unique sedimentary archive to develop orbital resolution geochemical records across five key climatic intervals of the Miocene (23-5.6 Ma) to better understand the impact of tectonics, global climate and regional monsoon strength on weathering and erosion regimes of the watersheds feeding into the Bay of Bengal. Benthic foraminiferal stable isotopes provide an orbital resolution stratigraphic framework and global climatic context while paired planktonic foraminiferal $\delta^{18}O$ and Mg/Ca proxies reflect SSTs and thus regional climate. Radiogenic Sr, Nd, and Pb isotope compositions of clays transported to the central Bay of Bengal suggest that the mixture of contributions from different erosional sources has overall remained remarkably consistent during the Miocene despite major tectonic reorganisations in the Himalayas. This mixture is relatively enriched in supplies from the formations with more radiogenic Nd

isotopes, which are today found in areas with the highest monsoon rainfall, suggesting a persistence of the preferentially eroded sources even to the present day. Nevertheless, high resolution data from the five intervals show marked fluctuations of all three isotope systems on orbital timescales. These transient excursions reflect changes in the balance of contributions from the High Himalayan Crystalline, Tethyan Sedimentary Series and Indo-Burman Ranges, which were mainly climatically driven given that the rapidity and transient nature of these changes cannot have resulted from tectonic events. Interestingly, the variability of these fluctuations is much higher during the peak warmth interval from 15.8 to 15.3 Ma within the Middle Miocene Climatic Optimum (MMCO) and across the major Miocene global cooling step from 14 to 13.5 Ma, compared to younger intervals deposited after the cooling, suggesting climatically induced changes in the erosion and weathering regime. Furthermore, while exhibiting little systematic variability during the warm MMCO, the clay Pb isotope signatures closely follow benthic $\delta^{18}O$ values during the major mid-Miocene global cooling step and thereafter. This observation suggests a direct link between global ice volume and climate and the Pb isotope composition of clays that only exists during colder periods. The onset of the major Miocene cooling is also marked by a peak in radiogenic Pb and Sr and unradiogenic Nd isotope values, suggesting higher contributions of Himalayan sources, possibly supplied as a consequence of increased penetration of monsoon precipitation into the mountains. All these findings clearly argue for a dominant climatic control of the erosion and weathering of the mountains surrounding the Bay of Bengal throughout the Miocene.

IODP

Mechanisms of glacial/interglacial climate variability during the Late Oligocene

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The Oligocene represents a transitional phase of Cenozoic climate evolution and marks the onset of the Cenozoic "icehouse" that is thought to have commenced with the initiation of large ice sheets on Antarctica (e.g., Zachos et al., 1996; Coxall et al., 2005). Superimposed on established global long-term trends in benthic foraminiferal oxygen isotope ($\delta^{18}O$, Zachos et al., 2001), the Oligocene is intersected by a number of sudden and large short-term shifts in $\delta^{18}O$ (~1 ‰, Oi-events, Miller and Katz, 1987; Miller et al., 1991; Pekar and Miller, 1996; Wade and Pälike, 2004; Pälike et al., 2006), which are interpreted to represent Antarctic glaciations since direct evidence for significant northern-hemispheric ice is lacking before 3.0 Myr ago (e.g., Larsen et al., 1994). However, detailed comparisons of available $\delta^{18}O$ records for the late Oligocene reveal opposing signals: While records from mid- to low latitude regions indicate a long-term warming trend (decreasing $\delta^{18}O$ values), records from the high-latitude Southern Ocean imply only low-amplitude climate fluctuations and little to no ice-sheet variability with an Antarctic Ice Sheet (AIS) near or even larger than modern size (Hauptvogel et al., 2017; Liebrand et al., 2017). Thus, although our understanding of Oligocene climate evolution has been greatly improved by previous studies, research is faced with a conundrum of concomitant deep-sea warming and stable AIS during the late Oligocene.

In order to address this paradox, we targeted late Oligocene drift sediments from IODP Site U1406 (Expedition 342) in the western North Atlantic. These drift sediments accumulated faster than typical deep-sea sediments (i.e., 2.2 cm/kyr), which allowed for sampling at a relatively high temporal resolution (~600–800 yrs) during the studied interval from 25.78 to 25.94 Ma. To estimate ice-volume and deep-water temperature changes, we paired new high-resolution benthic foraminiferal oxygen isotope ($\delta^{18}O$) and magnesium/calcium (Mg/Ca) records. These newly generated datasets have adequate fidelity to study the fundamental processes and mechanisms underlying ice-sheet waning and waxing on orbital timescales during the late Oligocene.

Our reconstructed bottom-water temperatures document only a minor contribution of bottom-water cooling to the $\delta^{18}O$ signal. We therefore argue that the fluctuations in $\delta^{18}O$ must primarily reflect changes in seawater $\delta^{18}O$ ($\delta^{18}O_{sw}$) by sequestering ^{16}O in glacial ice, causing a whole-ocean increase in $\delta^{18}O_{sw}$ rather than ocean temperature. The herein presented results suggest substantial waning and waxing of the AIS, ranging from an ice volume comparable to the modern to substantial melting of the AIS on obliquity timescales. These dynamics require the loss of up to 40% of the AIS within 20 kyr, which is a never-before-seen pacing for the late Oligocene cryosphere.

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ICDP

Genese eines der tiefsten Tälern der Ostalpen: Das quartäre Lienzer Becken

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Übertiefte Alpine Täler und Becken sind das Ziel des ICDP Projekts „Drilling Overdeepened Alpine Valleys" (DOVE; Anselmetti et al., 2016). Im Vorfeld von DOVE untersuchen wir das Lienzer Becken mittels hochauflösender Reflexionsseismik. Das Lienzer Becken in Osttirol (Österreich) liegt am Zusammenfluss mehrerer großer Eisströme während des Last Glacial Maximum (LGM) und bildet, als Teil des Oberen Drautals, eine der größten übertieften Strukturen im östlichen Alpenraum. Die maximale Tiefe des Beckens (622 m u. GOK) liegt im Bereich zweier Störzonen, die sich nicht direkt in den seismischen Profilen abbilden. Jedoch identifizieren wir Rinnenstrukturen in den seismischen Profilen, die möglicherweise durch eine verstärkte Erodierbarkeit des Festgesteins im Bereich der Störzonen entstanden sind. Am Übergang zum Oberen Drautals steigt die Beckenbasis mit 2,6 % an. Der Anstieg ist damit mehr als ein Faktor 5 größer als der entgegengerichtete Gradient der Eisoberfläche während des LGM (0,4-0,5 %; Reitner 2003). Eine solche Diskrepanz lässt auf ein Gefrieren der subglazialen Schmelzwässer schließen, was ab einem 1,2-fachen Wert beobachtet wird (Cook & Swift, 2012). Wir folgern daher, dass die übertiefte Erosion des Lienzer Beckens vor dem LGM mit steileren Gradienten der Eisoberfläche stattgefunden hat. Das Lienzer Becken weißt eine lokale Übertiefung von 146 m auf. Eine Integration weiterer Studien beziffert die gesamte Übertiefung des Oberen Drautals mit 530 m. In der Beckenfüllung interpretieren wir sechs verschiedene Einheiten anhand der seismische Fazies (Burschil et al., 2018): (1) subglazialen Till/glazio-lakustrine Ablagerungen, (2) lakustrine Sedimente, (3) fluviale Sedimente mit Schrägschichtung und (4) ohne Schrägschichtung, (5) grobklastische Ablagerungen und (6) Kies/Grobsand. Anhand der Sedimentabfolge können wir die Verfüllung des Lienzer Beckens rekonstruieren. Die Paläowassertiefe zu Beginn der Ablagerung der Seesedimente (2) können wir aufgrund der Übertiefung auf mindestens 216 m abschätzen.

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ICDP

Controls on outgassing versus the formation of impermeable networks during heating-induced vesiculation in rhyolitic magma

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Violent explosive eruptions generally pose some of the greatest threats to population and infrastructure in the earth system. Many of the largest explosive eruptions, with consequences that can reach the global scale, have been fed by rhyolitic magmas. The dynamics of magma degassing can exert a central influence on the explosivity of rhyolitic volcanoes via the role it plays in generating the bubble overpressure which is the source of the explosive energy of fragmentation. Bubbles grow in general via a combination of diffusion-controlled mass transfer from melt to bubbles, viscous relaxation of the melt, and decompressive volume expansion. The main driving force of oversaturation-driven nucleation and growth of water-rich bubbles is the temperature- composition- and pressure-dependent water solubility in the melt phase. Another key process affecting the explosivity of volcanic eruptions is the formation of impermeable or connected bubble networks; the latter can result in varyingly efficient outgassing, reducing the explosive energy in an eruption or even may inhibit it.

Here, we experimentally investigate the role of heating on rhyolitic magma vesiculation in a shallow conduit. The experiments were conducted using cylindrical (5 mm-diameter and 3 mm-height) samples of both natural and rehydrated rhyolitic glasses from Hrafntinnuhryggur, Krafla volcano, with low initial water contents (0.15-0.32 wt% H_2O). Samples were heated at variable rates (1-60 °C/min) to final temperatures of 750-1000°C in an optical dilatometer at 1 bar pressure, during which the evolution in time of sample volume, and therefore vesicularity, was monitored. During heating, sample volume increases nonlinearly due to bubble growth. Textural analyses performed using X-ray computed microtomography (μCT) and Scanning Electron Microscope (SEM) reveal low values of bubble number density (BND) for the natural obsidians and higher values for the rehydrated obsidians. The natural obsidians exhibit isolated bubble growth leading to the development of an impermeable bubble network. The rehydrated samples possess, in contrast, a high level of bubble connectivity that record significant bulk outgassing as evidenced by SEM and mass difference analyses. This starkly contrasting behavior is likely driven by the abruptness of water exsolution just above the glass transition temperature during heating. The presence of crystallinity in some samples also contributes to this thermal history of bubble nucleation and growth and the corresponding development of bubble connectivity yielding permeable pathways. Ongoing investigation is aimed at separating these effects.

IODP

Could decreased thermocline stratification drive ice-sheet build up during the Mid-Pleistocene Transition?

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The MPT marks the emergence of the 100-kyr glacial-interglacial cyclicity in the Quaternary with the most significant changes taking place between MIS 24 and 22 [1, 2]. Although there have been abundant studies on the MPT, the exact mechanism that caused the change of the climate response to insolation remains elusive. The current hypotheses explaining the shift in the dominant glacial/interglacial periodicity from 40 to 100 kyrs rely primarily on the enlargement of northern hemisphere ice sheets. Bigger ice sheets would have acted as a climatic buffer to orbital changes by being more resilient to warm spells, allowing for the emergence of the 100-kyr cyclicity. This ice-sheet expansion also coincides with the so-called “900 kyr event” within MIS 22, a time when the Atlantic Meridional Overturning Circulation (AMOC) substantially weakened resulting in prolonged cold sea-surface temperature (SST) conditions in the North Atlantic [3, 4]. Although cold background conditions favor the sustainability of large ice sheets, they also decrease the atmospheric moisture saturation level, raising questions about the moisture pathways necessary for extensive glacier growth in the Northern Hemisphere during that time. To investigate whether subsurface rather than surface heat transport helped to sustain warm temperatures in the northern North Atlantic during the MPT, we generated a record of subsurface temperatures at Integrated Ocean Drilling Project Site U1313 (41°N, 33°W, 3426 m water depth) across the interval between MIS 35 and 14. We assessed the heat capacity of the subtropical thermocline producing Mg/Ca-based subsurface temperatures from the deep-thermocline dweller foraminifera Globorotalia crassaformis. Our data show that thermocline stratification was extremely low at subtropical latitudes of the North Atlantic between MIS 24 and 22. The combination of our data with newly revised understanding of heat transport to the subpolar North Atlantic allowed us to infer that accumulated subsurface heat reached the surface of the subpolar North Atlantic, particularly during MIS 22. The resultant relatively warm high-latitude SST would have provided a potent moisture source for glacier growth. Our data further indicate that mid-latitude stratification in the North Atlantic is predominantly driven by low-latitude processes, and might therefore act as a mediator for imposing low-latitude climate pacing onto high-latitude glacial ice-sheet dynamics. The combination of this precession-paced low-latitude mechanism for subsurface heat transport into the North Atlantic with the pre-existing obliquity modulation of ice-sheets may have contributed to the emergence of the 100 kyr beat during the MPT [5, 6].

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IODP

Magnetostratigraphic framework for IODP Expedition 371 (Tasman Frontier Subduction Initiation and Paleogene Climate): preliminary results.

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International Ocean Discovery Program (IODP) Expedition 371 (27 July - 26 September 2017) was designed to understand the Tonga-Kermadec subduction initiation through recovery of Paleogene sedimentary records, and also to constrain the regional oceanography and climate evolution since the Paleogene. During the Expedition were drilled 2506 m of sediment and volcanic rock at six sites located in the northern Zealandia and Tasman sea area (Figure 1). Sediments drilled at Sites U1506 to U1510 consist of nannofossil and foraminiferal ooze or chalk that contained volcanic or volcaniclastic intervals with variable clay content. Paleocene and Cretaceous sections range from more clay rich to predominantly claystone.

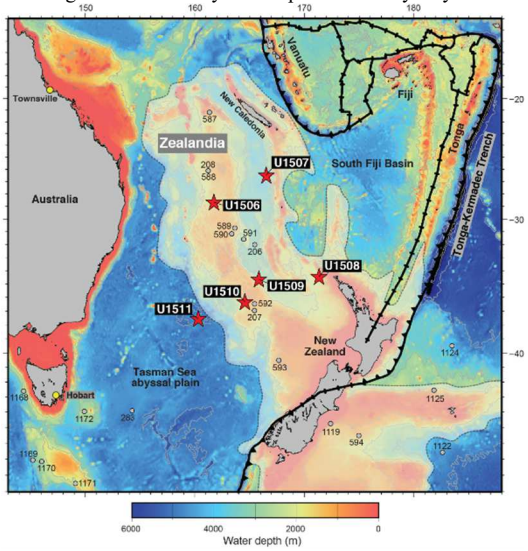

Figure 2: Bathymetry of the Southwest Pacific-Tasman area. Stars indicate sites drilled during Exp. 371; the black dashed line envelops the Zealandia continental crust.

At Site U1511 a series of abyssal clay and diatomite was recovered, with only minor amounts of carbonate. The ages of strata at the base of each site were middle Eocene to Late Cretaceous (Sutherland et al., 2018). In order to integrate paleomagnetic results from shipboard archive halves and discrete specimens measurements, during the sampling party that followed the expedition we collected a total of ~400 standard 8 cm3 oriented cube specimens. Specimens were stepwise demagnetized using both alternate field (AF) and thermal demagnetization, and the natural remanent magnetization (NRM) was measured after each demagnetization step with a 2G Enterprises Cryogenic magnetometer. Overall, we obtained reliable paleomagnetic results suitable for magnetic polarity correlation in Hole U1507B, U1508C, U1509A, and U1511B. Altogether they span from magnetic polarity Chron C6C to C15 (23 - 35 Ma), and from Chron C18 to C24 (39-53 Ma). In the international time scale this corresponds to the Aquitanian-Priabonian (lowermost Miocene to uppermost Eocene) and Bartonian-Ypresian (late to early Eocene), for a total of ~26 Myr of southwest Pacific geological history calibrated with the Geomagnetic Polarity Time Scale (GPTS; Ogg, 2012). This age-model provides a robust chronological framework for understanding the evolution of the Tonga-Kermadec subduction zone during the Cenozoic and the possible implications on the global climate variations.

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ICDP

Can we predict fluid pathways in the crust?

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It is commonly assumed that fluid pathways in the crust typically follow discontinuities. There is an apparent disconnect between field evidence and theoretical models. From spatial and geological observations, it is typically shown that volcanic vents cluster above pre-existing faults and that deep fluid degassing sites utilise permeable conduits, at least in the near surface. Such observations suggest that fluids rely on weaker discontinuities and are unlikely to propagate through a solid rock mass. Other evidence points counter to this; volcanic vent locations are scattered, typically lying some distance from well-defined fault traces; veins in rock masses and dykes in oceanic and continental crust cut directly through relatively homogenous groundmasses. Porous fluid flow is clearly a viable method to transport fluids in the crust, but we question its validity for highly pressurised buoyant fluids such as magma and in impermeable rock masses i.e. crystalline rock.

Theoretical models for fluid passageways in an isotropic rock mass assume the fluid is under enough pressure to crack its way through the medium. Such models base on fracture mechanics are simplistic, but put physical bounds on required fluid pressures, volume, density and rock toughness. Such models supply a reason for the difference in aperture of veins and dykes and provide bounds on the length scale of cracks containing a given fluid type. A surprising finding from these models is that the direction of the fluid pathways is sensitive to the ambient stress field, such that, with a good knowledge of this property and the physical parameters involved, the path of the fluid can be predicted.

We aim to show the development of such models up the present day and their relative accuracy while detailing their assumptions. We will then show our most recent adaptations to 3D use cases; one, predicting likely vent locations in Campi Flegrei caldera, Italy, and the other applied to an observed sill intrusion at Sierra Negra in the Galapagos islands. The end goal is to apply the method to fluid pathways in the Eger graben and Cheb basin.

IODP

A test of the Limacina Dissolution Index (LDX) as proxy for aragonite saturation of surface waters at Site U1460, SW Shelf of Australia

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IODP Site U1460 on the Carnarvon Ramp (SW Shelf of Australia) recovered a nearly continues Pliocene to Recent record of outer shelf sediments deposited at the transition between cool and warm water environments. The origin and composition of the carbonate sediments were investigated using scanning electron microscopy and X-ray diffraction. The aragonite content of these subtropical sediments reaches up to 30 % and originates mainly from maceration of ascidians spicules with minor amounts from bivalve shells, bryozoans, serpulid worms and pteropoda. Inorganic aragonite, such as reported for the Northern Carnarvon Basin, seems to be absent. X-ray diffraction analyses indicate a systematic decrease in aragonite content with depth. The Limacina Dissolution Index (LDX), is conventionally used as a proxy for changes in bottom-water corrosiveness with respect to aragonite. Recently, it has been proposed that LDX can also be used to reconstruct in-life dissolution and consequently the aragonite saturation of waters in which the pteropds calcified. We tested if LDX is suitable for the reconstruction of the aragonite saturation state of surface waters at Site U1460, which is situated far above the regional aragonite Iysocline. The downcore record of LDX at this site shows a shift from negligible dissolution (LDX 0-2) to strong dissolution (LDX 3-5) at around 6 m (CSF-A). This likely indicates that the LDX record is influenced by aragonite dissolution within

the sediment and cannot be used as a proxy for surface waters aragonite saturation.

IODP

An astrochronology for the lower to middle Eocene of the Mentelle Basin (Australia) and its implications for the geologic time scale

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The geologic time scale for the Cenozoic Era significantly improved over the last decades by virtue of advances in radioisotopic dating and the integration of these dates with astrochronologic and cyclostratigraphic results. However, to date the middle Eocene, remains a weak link. This so-called "Eocene astronomical time scale gap" reflects a lack of suitable study sections with clear astronomically forced variations in carbonate content, primarily due to large parts of the Eocene ocean being starved of carbonate. During International Ocean Discovery Program (IODP) Expedition 369, a carbonate-rich sedimentary sequence of Eocene age was recovered at Site U1514 in the Mentelle Basin (southwest Australia). The sequence consists of nannofossil chalk and exhibits a rhythmic character in its clay content. Hence, IODP Site U1514 provides an excellent opportunity to extract an astronomical signal and to construct an Eocene astrochronology. Here, we use X-Ray fluorescence (XRF) core scanning at 3 cm resolution to quantify the clay content variability. The XRF-derived ratio between calcium and iron content (Ca/Fe) precisely tracks the lithologic variability and serves as the basis for the U1514 cyclostratigraphic framework. Our astrochronology reveals a 16 million-year-long (40-56 Ma) nearly continuous history of Eocene sedimentation with variations paced by astronomical climate forcing. We supplement the high-resolution XRF data with low-resolution bulk carbon and oxygen isotopes, recording the long-term cooling trend from the Paleocene-Eocene Thermal Maximum (PETM) to the Middle Eocene Climatic Optimum (MECO). The well-expressed lithological alternations between clay-rich and clay-poor intervals reflect the combined imprints of obliquity and eccentricity. Our early Eocene astrochronology confirms existing chronologies based on deep-sea sites and Italian land sections. For the middle Eocene, the exceptional match of the tuned record at U1514 with astronomical solutions allows us to confirm astrochronologies previously suggested for the equatorial and South Atlantic (Sites 702, 1260 and 1263) and is an important step towards a fully astronomically calibrated Cenozoic geologic time scale.

ICDP

Palaeoenvironmental Messages from Lake Teletskoye, Sibirian Altay Mountains: State of Findings and future Perspectives .

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Lake Teletzkoye represents an intramontane tectonic lake at the northern margin of the Altay Mountains in southern Siberia (51.5°N, 87.7°E, 435 m a.s.l.). The elongated lake basin is 78 km long, 4-6 km wide, up to 325 m deep, and includes shallower isolated subaquatic ridges at about 100 m water depth. The depositional environment is dominated by clastic fluvial runoff and internal sediment dispersal by under- and interflows, preserved in clastic warves. Biogenic components mainly comprise diatom remains, algal organic matter, and pollen grains. Former seismic surveys have revealed an at least 300 m thick lacustrine sediment infill. Palaeolimnological studies so far were limited to short, only up to two meter long sediment cores, documenting palaeoenvironmental variability during the last 1500 years, related to centennial variations in runoff and vegetation dynamics. These promising findings highlight the Teletskoye sedimentary record to represent an unique palaeoclimate archive at the intersection of different central Asian climate regimes, passing over from the moist boreal forests of Siberia to the dry areas of inner Asia. According to modern sedimentation rates (≤1 mm/year), the sedimentary record may reach back to the mid-Pleistocene and even older, with a relatively high resolution of interglacial intervals compared to other lake records from Siberia (e.g. Baikal, El'gygytgyn). To test this assumption, another prestudy on longer sediment cores (10-20 m) is intended to examine the nature of glacial sediments in terms of their palaeolimnological eligibility. In addition, further seismic surveys are needed to scrutinize the Lake Teletskoye as a target for deep drilling.

ICDP

Reconstruction of glacial to interglacial biomass burning of northeastern Siberia during the last 270 kyrs

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Long-term fire regime shifts are major unknowns in the prediction of future environmental change in the high northern latitudes. Lake El'gygytgyn, northeastern Siberia, provides the only continuous Pliocene-Pleistocene sediment record of environmental conditions in the Arctic. Several proxies suggested prominent climate and biome shifts in the past under different boundary conditions – beyond human influence. Hence, El'gygytgyn sediment cores are unique archives to analyze high northern fire regime shifts on long time scales and during different climate states, with some past interglacials serving as natural analogues of predicted future climate change.

Here, we study the long-term fire regime history of Chukotka using sediment core PG1351. We focus on two intervals of the last 270,000 years that are characterized by similar summer insolation, but different global ice volume, and different vegetation composition. We aim to test (i) how far varying climate conditions and biome configurations are reflected in multiple fire regime proxies that are fire-intensity and severity specific, and (ii) how far external feedbacks as determined from climate and ice volume relationships and/or internal vegetation-permafrost feedbacks drive fire regime shifts in the high-northern latitudes.

Here, we present preliminary centennial and millennial scale records of multiple fire proxies from the same samples of MIS 5e and MIS 7e and their preceding glacials. We microscopically analyzed charcoals and spores of Gelasinospora (a fire disturbance indicator) from pollen slides. Ultra-high performance liquid chromatography-high resolution mass spectrometry was used to determine, for the first time in the terrestrial Arctic, records of the low-temperature biomass burning residues levoglucosan, mannosan and galactosan. We find significantly different fire proxy ranges, variability and ratios that allow characterizing fire regimes during the two interglacials and their preceding glacials. The comparison with climate and vegetation reconstructions from the lake and the region suggests that not only temperature, but also internal vegetation-permafrost feedbacks determine the specific configuration of fire regime parameters such as fire intensity on long time scales. These new results provide a step forward to understanding long-term feedbacks that are crucial for model predictions of future fire regime shifts in the high northern latitudes.

ICDP

Rupture Imaging and Directivity of the 2014 M5.5 Earthquake Below a Gold Mine in Orkney, South Africa

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We present a comprehensive study of seismicity from deep South African gold mines. Here, we find the unique situation that the seismicity consists of both mining-induced earthquakes and aftershocks triggered by the M5.5 Orkney earthquake which occurred in August 2014. We hypothesize that the finite size and geometry of the volume of stress perturbation, caused either by mining activities or by a large earthquake, controls the propagation of ruptures and influences the observed frequency-magnitude distribution. We use advanced approaches which involve both waveform-based and probabilistic methods. These methods include rupture propagation imaging and directivity analysis, and studies of the scaling of earthquakes magnitudes in finite perturbed rock volume. For the first time we apply these approaches to the observed seismicity in deep South African gold mines which also occurs in finite volume where the in-situ stress is perturbed. It contributes to a better understanding of seismogenic processes and, in particular, to an improved assessment of seismic hazard in an active mining environment. Our results indicate a unilateral rupture of the M5.5 main shock propagating nearly from North to South over a distance of about 5 km. The images of back-projected seismic energy as well as the retrieved source time function reveal a highly complex rupture process of this earthquake which complements other results (Imanishi et al., 2016, Moyer et al., 2017). Furthermore, we see a clear spatial separation between the triggered aftershock cloud and the induced seismicity in the different mining horizons. The aftershock cloud is unilaterally situated in respect to main shock epicenter and aligned to the South which confirms the obtained rupture propagation image and directivity. The magnitude statistics of both aftershocks and induced earthquakes are noticeable affected by the finite size of the perturbed rock volume which inhibits the occurrence of larger magnitude events. The statistic of the event waiting times however differ for the two types of seismicity. The distribution of aftershocks in time shows clearly the typical Omori-Utsu behavior (i.e., a strict power-law decay) whereas earthquakes in the mines are observed at a rather constant level of activity emphasizing a Poissonian nature of acausal occurring events induced by mining operations.

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IODP

Transport, Removal and Accumulation of sediments Numerically Simulated for Paleo-Oceans and Reconstructed from cores of The Eirik Drift (TRANSPORTED)

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The Wester Boundary Undercurrent (WBUC) flows around the Southern tip of Greenland and is a major contributor to the lower branch of the Atlantic Meridional Overturning Circulation (AMOC). It is mainly driven by deep water producing convection processes in the Nordic Seas and thus sensitive to atmospheric changes on a broad spectrum of time scales. A major present concern is the impact of long term climate change on both strength and flow path of the current. However, such time scales also include tectonic modifications as a contribution to alterations of the flow. The investigation of the state of the circulation in past geological epochs is feasible by means of sediment drift bodies which are plastered by the deep current along the lower shelf slope, e.g. the Eirik Drift on the Southern slope of Greenland. Seismic profiles (e.g., Müller-Michaels and Uenzelmann-Neben (2014, 2015)) and drill cores (Expedition 303 Scientists (2006), Shipboard Scientific Party (1987)) allow the determination of sedimentation rates and grain sizes since the late Miocene and the Pliocene. Such studies showed pronounced modifications during both the Miocene and the Pliocene which are especially geological epochs of interest to the climatological community due their resemblance to possible future anthropogenically modified climate states (Salzmann et al. (2009)). Several numerical climate and ocean studies have linked local temperature and precipitation proxies to global climate changes during the late Miocene and the Pliocene. In the project TRANSPORTED we aim to link tectonic events and climate change to alterations of the strength and flow paths of the WBUC and, hence, to sedimentation rates and grain sizes recorded in the cores from Sites 646 and U1305-1307 in the Eirik Drift.

Density-driven deep currents in geostrophic balance show distinct features such as sustained widening while reducing velocity and pronounced narrow eddies at the bottom. These currents therefore produce an equally distinct sediment structure: a strong erosion channel and enhanced deposition downstream, as has been described by Rebesco et al. (2014)). We were able to reconstruct such currents successfully at a very high horizontal and vertical resolution along the southern slope of Greenland enabling us to drive our sediment module at most realistic conditions. Extracting grain sizes and densities of the main material deposited in the area of investigation from the previous sedimentological studies, we were able to conduct the first sensitivity studies altering tectonic and atmospheric parameters. These studies show a significant but moderate response to the modifications under present conditions but changes may be more pronounced for the conditions of past geological epochs when local deposition rates were peaking (Müller-Michaelis, Uenzelmann-Neben (2014)). Therefore, our next aim is to conduct paleological simulations under past climate forcing and crucial tectonic changes in order compare numerical results and sedimentological output.

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IODP

Achieving a global late Miocene stable oxygen isotope reference stratigraphy spanning 8.00-5.33 Ma

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Accurate stable oxygen isotope ($\delta^{18}O$) stratigraphy remains fundamental to investigating past deep-sea ocean temperatures and global ice volume. High-resolution Plio-Pleistocene benthic $\delta^{18}O$ stacks, like the global LR04 (Lisiecki and Raymo, 2005) and the regional equatorial Atlantic Ceara Rise (Wilkens et al., 2017) stacks, are essential to improving our understanding of climate dynamics for the last 5 Myr. However, a comparable high-resolution, precise late Miocene compilation does not yet exist.

Here we present our efforts to compile a high-resolution global benthic $\delta^{18}O$ reference stratigraphy for the late Miocene covering the interval from 8.00-5.33 Ma. To achieve this, it is crucial that records are stratigraphically verified to avoid duplication or concealment of individual cycles. It is also key to include multiple high-resolution records from the major oceanic basins to avoid miscorrelation and aliasing of short-term excursions as late Miocene benthic $\delta^{18}O$ is notably low-amplitude.

Until recently, suitable high-resolution late Miocene benthic $\delta^{18}O$ records were limited to those from Atlantic ODP Sites 982 and 926, which respectively had an unverified shipboard splice and only extended to 7 Ma. We first developed a stable isotope and magnetic polarity reference section at Pacific IODP Site U1337 to underpin the global stack. The Site U1337 stratigraphy was combined with high-resolution records from IODP U1338 to accurately constrain the Pacific endmember. We targeted ODP Sites 982 (North), 926 (equatorial) and 1264 (South) to obtain equivalent Atlantic records. At all three sites, we verified existing splices, generated isotope data to fill uncovered gaps and extend records back to 8.0 Ma, and finally established independent astrochronologies.

Combining the new high-resolution records, we have accomplished our ultimate goal of generating a global benthic $\delta^{18}O$ stack between 8.00-5.33 Ma, which represents a stratigraphic late Tortonian-Messinian reference section accurately tied to the Geomagnetic Polarity Time Scale. In the new benthic $\delta^{18}O$ stack, we verify the existing Marine Isotope Stages (MIS) between 6.5 and 5.33 Ma and additionally recognise 68 new MIS between 7.7 and 6.5 Ma. There is exceptional agreement between the records from different sites between 7.7-6.9 & 6.4-5.4 Ma, when a strong 40 kyr heartbeat dominates.

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ICDP

Differentiating local from regional climate signals using the ~600 ka Chew Bahir paleoclimate record from South Ethiopia

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Cores from terrestrial archives, such as the lacustrine sediments from the Chew Bahir basin in southern Ethiopia, which cover the last ~600 ka, often reflect both local, regional and global climate influences. In our analysis we were able to identify several time windows in which the Chew Bahir climate is in resonance with regional and global climate change.

As a contribution to understanding and differentiating these connections recorded in the Chew Bahir sediments, we have correlated the 2nd principal component of the MSCL based color reflectance values representing wet conditions in the Chew Bahir basin, with the wetness index from ocean core ODP 967 from the eastern Mediterranean Sea. The correlation between these two time series was calculated using the Spearman correlation coefficient in a sliding window. Episodes with high correlation between the two records of wetness could indicate a strong link between both regions, possibly through an increased outflow of the river Nile into the eastern Mediterranean Sea due to higher precipitation values on the Ethiopian plateau.

Our preliminary results show that when correlating the two records, two distinct temporal units can be distinguished. Between ~570 ka and ~350 ka the correlation is dominated by cycles that correspond with orbital precession whereas the second unit (after 350 ka) reveals a strong influence of atmospheric CO_2. This observation suggests that both orbital precession and atmospheric CO_2. may cause a synchronization of different regions in the African climate system, possibly depending on boundary conditions which are still to be identified.

As a next step we'll investigate the nonlinear relationships between the two records by focusing on the transition between the two main observed phases. The transition around ~350 kyrs however, is not only highly interesting from a climatic perspective, but it is also a noteworthy period for human cultural evolution as a transition from Acheulean to Middle Stone Age (MSA) technologies takes place at this time. So far our results outline that during this climatically and evolutionary relevant episode a relatively stable, long-lasting, pan-African wet phase may have existed, with possible green corridors connecting the habitats of hominins, and ample resources supporting large population sizes.

ICDP

Cr isotopes in 2.5 to 2.0 billion-year-old sediments from Fennoscandia as tracer for Paleoproterozic atmospheric oxygen levels

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The ~2.45-2.32 Ga Great Oxidation Event (GOE) marks the first significant increase in atmospheric oxygen levels and defines the transition from anoxic to oxic surface conditions (Holland, 2002). The aftermath of the GOE records perturbations of the carbon, sulfur and oxygen cycles, but the atmospheric oxygen evolution remains poorly understood. Here, chromium (Cr) isotopes may provide additional constraints on the post-GOE atmospheric oxygen levels, because oxidation of immobile Cr(III) to mobile Cr(VI) during oxidative weathering induces a large isotope fractionation and is therefore suggested as a tool for tracing Earth's surface oxygenation evolution (Frei et al., 2009).

The ICDP FAR-DEEP (Fennoscandia Arctic Russia – Drilling Early Earth Project) drill cores cover approximately 500 million years after the GOE and sample terrestrial and marine sedimentary environments, providing an important archive for understanding Earth's post-GOE redox evolution. In order to provide new insights into Earth's post-GOE redox state, we sampled several FAR-DEEP drill cores from the Pechenga Greenstone Belt and the Onega Basin during an international workshop at the Geological Survey of Norway (NGU, Trondheim) in May 2018 and present a preliminary Cr isotope record of the different surface environments archived in these drill cores. The oldest sediments from the 2.4 Ga Polisarka Sedimentary Formation show unfractionated Cr isotopes, indicating that Cr was not oxidized and mobilized on the continents. Stromatolitic carbonates from the 2.056 Ga Kolosjoki Sedimentary Formation show negative $\delta^{53}Cr$ values, which most likely indicates that organic matter (OM) of the stromatolites reduced soluble Cr(VI) to Cr(III), which then adsorbed onto the charged OM surfaces. In order to evaluate this process, we are comparing these Paleoproterozoic stromatolites with microbial carbonates through Earth's history. The difficulty here is that carbonates contain only small amounts of Cr and we therefore refined a method that allows determining the Cr isotopic composition of low-Cr carbonates. Our first Cr isotope data on Neoarchean stromatolites from the Campbellrand carbonate platform (South Africa) show unfractionated $\delta^{53}Cr$ values. 2.2 Ga old terrestrial carbonates (travetines), 2.0-1.9 Ga old shungites, bituminous seeps deposited in a brackish lagoonal setting and 2.056 Ga old marine hydrothermal jaspilitic deposits all show exclusively positive $\delta^{53}Cr$ values, pointing to efficient Cr(VI) reduction and Cr(III) adsorption, thereby mirroring the heavy isotopic composition of the original soluble chromate ($Cr^{(VI)}O_4^{2-}$). Our Cr isotope data identify significant atmospheric O_2 levels,

which caused intensive oxidative continental weathering at 2.2 Ga that delivered mobile Cr(VI) with positive $\delta^{53}Cr$ values into the Paleproterozoic oceans.

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IODP

Combined micropaleontological and biogeochemical reconstruction of Late Miocene Ross Sea (Southern Ocean) paleoenvironmental conditions

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Abstract

International Ocean Discovery Program Expedition 374 drilled a latitudinal and depth transect of five drill sites from the outer continental shelf to the rise in the eastern Ross Sea to resolve the relationship between climatic and oceanic change and West Antarctic Ice Sheet (WAIS) evolution through the Neogene and Quaternary. WAIS collapse events during past warmer-than-present climates may be the consequence of intensified ocean-cryosphere interactions. Interactions between the wind-driven upwelling of warm Circumpolar Deep Water (CDW) and the ice shelves that buttress the WAIS appear to play a significant role in modern ice mass loss in West Antarctica. It needs to be proven, that changes in either the formation of Antarctic Shelf Water (AASW) and Antarctic Bottom Water (AABW) or the vigor of the wind-driven Antarctic Shelf Current control incursions of CDW onto the Ross Sea continental slope and shelf and the resultant retreat of the WAIS. The records from Expedition 374 will allow to address this issue by e.g. assessing changes in sea surface temperature and ice sheet extent in the Ross Embayment (Sites U1521, U1522, DSDP Site 272, and ANDRILL). Reconstructions of past glacial and open-marine conditions at Site U1521 will give insight into environmental changes on the Antarctic continental shelf during the early and mid-Miocene. At Site U1522, a discontinuous sequence of glacial and glaciomarine strata of upper Miocene was recovered from the outer shelf, complementing the sequences of Site U1521.

Main goal of this joint micropaleontological and biogeochemical project is to gain insight into the paleoenvironmental development of the inner Ross Sea and the adjacent WAIS during the Miocene with special emphasis on the Miocene Climatic Optimum (MCO) and the Miocene Climate Transition (MCT) to a colder period of Earth's history. To address past changes in productivity, sea surface temperatures and sea ice extent, a combination of diatom analysis (census) and biomarker studies will be applied to selected samples from sites U1521 and U1522. Changes in diatom assemblage composition provide qualitative information on sea surface temperature and sea ice cover and will be complemented by TEX86-based estimates of water temperatures and an assessment of primary productivity variability using e.g. phytosterols and highly branched isoprenoids. Results will be compared to previous findings from DSDP Site 272 and ANDRILL, generating a sequence of evidence for environmental change in the Ross Sea throughout the Late Miocene.

ICDP

Oman Drilling Project: Cooling rates of the lower oceanic crust determined from diffusion chronometry

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Models of crustal accretion along fast-spreading mid-ocean ridges differ in the proportion of crystallization at different depths within the lower oceanic crust. Therefore, these models predict different thermal evolution, and most significantly, different depths to which hydrothermal fluids circulate in the oceanic crust. As a consequence, this implies different rates of cooling as a function of depth. 'Gabbro glacier' type models require most of the latent heat of crystallization to be removed by hydrothermal circulation at the top of the axial magma chamber, leading to fast cooling rates in the upper gabbros. With increasing depth, heat conduction becomes the dominant process of heat removal. Since heat conduction is a less efficient mechanism of heat removal than hydrothermal circulation, it is expected that cooling rates decrease with increasing depth. In contrast, in 'sheeted sill' type models, the mechanism for heat removal (hydrothermal circulation) is the same over the entire depth of the gabbroic crust and, therefore, cooling rates are not expected to change as a function of depth. The determination of cooling rates of rocks from different depths within the oceanic crust therefore provides insights in the processes involved in its formation.

The Chikyu Oman Drilling Project is a multi-national collaboration to explore ancient seafloor in the Samail Ophiolite in the Oman, which is generally believed to be the best analogue of a fast-spreading ridge system on land. Drilling started in 2017, and to date, the program has sampled the ophiolite sequence from crust to basal thrust in multiple boreholes. The total cumulative drilled length is approximately 5500m. These cores were logged to IODP standards aboard the DV Chikyu during two 60-day description campaigns (2017 and 2018).

The freshest gabbroic rock samples from Holes GT1A and GT2A were chosen to obtain subsolidus cooling rates using the recently developed Mg-in-plagioclase diffusion chronometer. Diffusion chronometers make use of the temperature dependence of the diffusive exchange of elements between different phases and thus allow the determination of cooling rates from diffusion modeling.

Preliminary data indicate cooling rates of 0.009-0.001°Cyr^{-1}, and decreasing cooling rates with increasing depth in the lower oceanic crust. These preliminary data support models of crustal accretion that require faster cooling at the top of the plutonic crust and slower cooling at deeper levels.

ICDP

Deciphering climate information from authigenic mineral transformations in the Chew Bahir sediment cores

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The Chew Bahir Drilling Project (CBDP), as an integral part of ICDP-co-funded Hominin Sites and Paleolakes Drilling Project (HSPDP), has recovered duplicate sediment cores from the Chew Bahir Basin in southern Ethiopia to test current hypotheses on human-climate interaction during the development of anatomically modern humans and their migrations out of Africa (Cohen et al., 2016). However, as in most terrestrial archives, deciphering paleoclimate from lake sediments is a challenge because of the complex and site-specific relationship between climate parameters and sediment composition. Determining and analyzing suitable climate proxies that are preserved throughout the core is key to a high resolution, continuous record on climate change.

Here we present first results from our ongoing work on deciphering direct paleoenvironmental information from authigenic mineral transformations in the long Chew Bahir sediment cores. In a hydrologically restricted setting, such as in Chew Bahir, the composition of authigenic clay minerals and zeolites are strongly controlled by the hydrochemistry of the paleolake that in turn responds to fluctuations in the precipitation-evaporation balance. In a pilot study, the Chew Bahir mineral assemblages, especially the abundant clay minerals, have been shown to react sensitively to variations in paleosalinity and alkalinity by finely adjusting their crystallographic composition (Foerster et al., 2018). Since the ~293-m-long Chew Bahir composite core is dominantly comprised of those highly reactive minerals the material is well-suited to provide continuous paleohydrochemical and eventually paleoclimatic information through mineralogical and geochemical analyses, especially where other indicators are only preserved intermittently. Whole-

rock (bulk) XRD analyses in a 32 cm resolution have been completed and results indicate that authigenic alteration during the last ~600,000 years can be linked to paleohydrochemistry and back to changing climatic conditions. Clusters with characteristic mineral assemblages for wet, dry and hyper-arid phases throughout the long core have been identified and clustered using a Principal Component Analysis of the XRD data set. This will eventually enable us to a) link mineralogy (XRD) with geochemistry (µXRF), b) define depositional conditions and environmental thresholds through time and c) start deciphering climatic change on orbital to decadal timescales. In summary, the results from the authigenic mineral analyses provide an important contribution to the understanding of complex climate proxy formation, enable deciphering of continuous paleoclimate information from the Chew Bahir sediment cores, and contribute data that may be essential for testing hypotheses of the impact of climatic change on human evolution and mobility.

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IODP

Geomorphology of the Belize Barrier Reef margin: a survey for IODP drilling

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As precondition for IODP drilling along the Belize Barrier Reef, the largest reef system in the Atlantic Ocean, a detailed bathymetric study is planned along selected section of the forereef area between ca. 20-150 m water depth of this major reef margin using multibeam and shallow seismic techniques. To date, no detailed and GPS-controlled bathymetry and continuous high-resolution seismic data of this barrier reef margin exists. Based on the data to be acquired, we intend to select suitable sites for IODP drilling. We aim at locating fore-reef sites, which will be suitable to recover postglacial (20-10 kyr BP) and underlying older Pleistocene deposits along a series of core traverses. Furthermore, an international workshop is planned to bring together some 10 interested scientists in order to explore the possibilities of developing a drill proposal for the IODP.

The subsequent IODP proposal could have four potential objectives including the reconstruction of postglacial sea-level rise, to analyze and quantify postglacial reef composition and architecture as response to sea-level and climate change, and to obtain environmental data on temperature and carbonate saturation during that time window. In addition, aspects of Pleistocene reef initiation and paleoecology may be investigated, depending on recovery in older Pleistocene succession. In the light of the modelled 21 century increases in sea-level rise, especially postglacial drowned reef sequences along the Belize margin can potentially be used for future sea-level projections. In contrast to the Indo-Pacific region where several highly resolved and scientifically robust reef-based postglacial sea-level records have been acquired (Huon Peninsula, Tahiti, Great Barrier Reef), there is only one such record in the tropical western Atlantic (Barbados, eastern Caribbean). The Barbados sea-level record is curious however, in the light of the fact that of meltwater pulses (MWP) 1A and 1B only the former has been detected in the recently acquired sea-level data from Tahiti (IODP leg 310) and the Great Barrier Reef (IODP leg 325). Also, abundant postglacial microbialite facies as found in the Tahiti and Great Barrier Reef and many other early Holocene reefs is apparently absent in Barbados for hitherto unknown reasons. Especially the abundance of microbialite facies in postglacial reefs is significant as proxy data (thickness, volume) from these comparably simple organisms (bacteria) are largely environmentally controlled and presumably easier to interpret as proxy data (sclerochronology, $\delta^{18}O$, Sr/Ca) from encymatically controlled reefal framebuilders such as stony corals. It has been debated whether microbialite abundance is linked to the nature of the hinterland, carbonate saturation, and rate of sea-level rise. In summary, a second postglacial reefal archive from Belize would certainly help to answer these open and debated questions and to constrain the nature of postglacial sea-level rise in the western Atlantic / Caribbean realm.

IODP

A Revised Core-Seismic Integration in the Molloy Basin (ODP Site 909): Implications for the History of Ocean Circulation in the Arctic-Atlantic Gateway

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The modern polar cryosphere reflects an extreme climate state, which developed through stepwise global Cenozoic cooling. In this context the polar gateways played pivotal roles in changing the global hydrography. The Arctic Ocean was isolated from any global thermohaline circulation system during large parts of its Cenozoic history. This gradually changed when Greenland and Svalbard started to move apart from each other initiating the opening of the Arctic-Atlantic Gateway (AAG), the only deep-water connection, which allows an exchange of water masses both at the surface and at depth with the World's oceans (e.g., Rudels 2015). Based on DSDP and ODP drilling campaigns (Legs 38, 104, 151, 162), and with the help of geophysical datasets, knowledge on the tectonic evolution of the Northeast Atlantic Basins and continental margins increased. However, crucial issues like the exact timing of tectonic phases and stratigraphic events and how these phases and events translate into seismic reflection stratigraphy are still a matter of debate. Previous seismic processing and interpretation in the area concentrated on the general low-resolution picture of the basement structure and overlying sediments and a first general interpretation of the glacial history along the NE Greenland margin (Berger and Jokat, 2009). In our study we re-process the available reflection seismic data with means of f-k-filtering and deconvolution in order to improve the resolution of the internal sedimentary structure and to achieve a better insight into internal reflection characteristics and the geometry of the sediment packages. Here we present first re-processed seismic lines that were collected in 2002 with RV Polarstern in the Molloy basin. We can demonstrate that we gain much higher resolution in the uppermost section, which significantly improves the interpretation of the shallowest part of the seismic profiles. An important profile is line AWI-20020300 that crosses ODP Site 909 (Myhre et al., 1995), a key site to date the late opening phase of the Fram Strait and the early history of the current evolution. P-wave velocity measurements combined with density data from core measurements and from downhole logging at Site 909 are used to calculate impedance contrasts and hence synthetic seismograms which allow us to project lithostratigraphic boundaries and age information derived from core analyses into the seismic grid. Crucial in this context is a prominent Miocene reflector dated at ~14 Ma by Berger and Jokat (2009), for which new palynological results within the framework of our project suggest a significantly younger (late Miocene) age.

IODP

Orbital Variations of Sediment Provenance and Deep Water Flow in the Indian-Atlantic Ocean Gateway Investigated with Physical Property and XRF Data from IODP Site U1475 (Agulhas Plateau)

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In 2016 the International Ocean Discovery Program (IODP) Expedition 361 ("SAFARI") recovered complete high-resolution Plio-/Pleistocene sediment sections at six drilling locations on the southeast African margin and at the oceanic connection between the Indian and South Atlantic Oceans. Site U1475 is located on the southern flank of the Agulhas Plateau, proximal to the entrance of North Atlantic Deep Water (NADW) to the Southern Ocean and South Indian Ocean. The site was drilled into a sediment drift in 2669 m water depth and comprises a complete carbonate rich (74 – 85%) stratigraphic section of the last ~7 Ma. The contourite deposits hold detailed information on past changes in the bottom water flow history in the Indian-Atlantic ocean gateway. Here we present results from the integration of physical properties, seismic reflection data, and major element records. The whole spliced sediment record (292 meters) of Site U1475 was measured using an X-ray fluorescence (XRF) core scanner to derive multi-centennial resolution records of major element intensities. Based on these measurements it is possible to derive biogenic (e.g. %$CaCO_3$) and siliciclastic (e.g. TiO_2, K_2O) mineral phases. Elemental log-ratios, such as Ca/Ti and K/Fe, reflect variations in biogenic ($CaCO_3$) vs. terrigenous supply and variability of the terrigenous provenance, respectively. While long-term changes in physical properties and elemental ratios can be linked to the seismic reflection patterns associated with deep water circulation changes, short-term cyclicities reflect Plio-Pleistocene climate variations at Milanlovitch-frequencies. Evolutionary spectra show that the orbital control on sediment composition was variable over time. During the last 4 Ma energy is concentrated at the 41ka band of obliquity and at lower frequencies. In contrast, the orbital precession cycle (19-23ka) is very prominent in a peculiar high sedimentation rate interval in the early Pliocene (~4 to 5 Ma) that is bounded by seismic reflectors and characterized by the development of sediment waves.

ICDP

Deriving paleoclimatic information from the degree of authigenic mineral alteration

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The Chew Bahir Drilling project is part of the Hominin Sites and Paleolakes Drilling Project (HSPDP), aiming at an enhanced understanding of climatic influences on human physical and cultural evolution (Cohen et al., 2016). The 280 m-long Chew Bahir lacustrine record, recovered from a tectonically-bound basin in the southern Ethiopian rift in late 2014, covers the past ~600 ka of environmental history, a time period that is of high relevance for the origin and dispersal of modern Homo sapiens. Finding reliable climate indicators that are also preserved throughout the core is challenging however. In a pilot study, the Chew Bahir mineral assemblages, especially the abundant clay minerals, have been shown to react sensitively to variations in paleosalinity and alkalinity by finely adjusting their crystallographic composition (Foerster et al., 2018).

First results from our ongoing mineralogical analyses on the long (~280 m) Chew Bahir sediment cores suggest that the degree of authigenic mineral alteration is indicative for wet, dry and hyper-arid climate intervals. Preliminary work shows that the most extreme evaporative phases are represented by authigenic mineral assemblages including Mg-enriched clays, low-temperature authigenic illite and euhedral analcime. For a reliable paleohydrological identification and interpretation of the multiple authigenic clay mineral phases, we compare air-dried (N), ethylene-glycol solvated (EG) and 550°C heated samples (dehydroxylation). This enables us to infer variations in alkalinity in between samples. The (060) reflection, measured in selected clay seperates, are indicative for the di- vs. trioctahedral character and changes in the octahedral occupancy of the authigenic clays, providing key information about changes in salinity. SEM and Energy Dispersive Spectrometer (EDS) analyses confirm that the variations in the analcime abundance that are evident in the XRD bulk dataset seem to be distinctly formed deltoidal icositetrahedrons. These are known to form in highly saline and alkaline brines (pH 9 and higher) and can be associated with pronounced arid phases.

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ICDP

The Nam Co Drilling Project, Tibet (NamCore): A one million year sedimentary record from the third pole

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The 2880 m long Lomati water tunnel traverses the two facing, subvertically dipping fold limbs of the Saddleback Syncline in the Barberton Greenstone Belt, exposing volcanic and siliciclastic strata of the Moodies Group (~3224 – ~3218 Ma) of about 1000 m thickness each. This unit represents some of the world's oldest well-preserved tidal, deltaic and terrestrial strata and bears global significance. Key strata are currently targeted by an ICDP full proposal (resubmitted January 2019) because they uniquely constrain multiple Paleoarchean environmental parameters.

The exposed tunnel sections ideally complement Moodies cores to be obtained from 6 nearby sites (each of 400-900 m length) by extending their stratigraphic range significantly. Traversing the strata, nearly unstrained despite crossing a nearly isoclinal hinge (a well-known and only partially understood phenomenon in the BGB) will allow to test several hypotheses related to the structural geology of greenstone belts and their often syndepositional deformation.

The open, partially flooded tunnel usually measures 3 m by 3 m; samples are best taken with a rock hammer and the tour best conducted by a team of four (sampling, labelling, photography, pulling a rubber dinghy). Tunnel sampling offers an uniquely low-risk, repeatable, detailed and highly cost-effective access to Archean samples unaffected by deep oxic weathering.

In a global context, tunnel samples will add to the BASE project objectives of (1) shedding light on rapid syndepositional deformation in non-actualistic, highly mobile, non-plate-tectonic setting, of (2) Early Earth surface conditions in a stratigraphic resolution comparable to the Holocene and (3) on the adaptation of abundant microbial life to early-Earth inhospitable surface environments.

IODP

The analytical performance of handheld XRF tested using marine sediments of IODP Expedition 355

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Obtaining geochemical profiles using X-ray fluorescent (XRF) techniques has become a standard procedure in many sediment core studies. The resulting datasets are not only important tools for paleoclimatic and paleooceanographic reconstructions, but also for stratigraphic correlation (Croudace and Rothwell 2015). The International Ocean Discovery Program (IODP) has therefore recently introduced shipboard application of a handheld XRF device, making geochemical data directly available to the science party. In all XRF scanning techniques, the physical properties of wet core halves cause substantial analytical deviations (Weltje et al. 2015; Weltje and Tjallingii, 2008). We test if results from the handheld XRF analysis on discrete samples are suitable for calibrating scanning data. Log-ratios with Ca as a common denominator were calculated and the comparison between the handheld device and conventional measurements shows that the later provides high quality data of Al, Si, K, Ca, Ti, Mn, Fe, Zn, Rb and Sr content (R2 compared with conventional measurements: ln(Al/Ca) = 0.99, ln(Si/Ca)=0.98, ln(K/Ca)=0.99, ln(Ti/Ca)=0.99, ln(Mn/Ca)=0.99, ln(Fe/Ca)=0.99, ln(Zn/Ca)=0.99, ln(Sr/Ca)=0.99. Our results imply that discrete measurements using the shipboard handheld analyser are suitable for the calibration of XRF scanning data. Our test was performed on downcore sediments from IODP Expedition 355 that displays a wide variety of lithologies of both terrestrial and marine origin. The implication is that our findings are valid on a general scale and that shipboard handheld XRF analysis on discrete samples should be used for calibrating XRF scanning data.

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IODP

From inorganic aragonite to skeletal calcite: Climate as a major control on carbonate mineralogy during the late Quaternary, NW-Shelf of Australia (NWS)

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Inorganic precipitation of aragonite is a common process within tropical carbonate environments. Across the NW-Shelf of Australia (NWS) such precipitates formed in high abundance during the last glacial, while present-day sedimentation is dominated by calcitic bioclasts. This contradicts observations from many shallow-water tropical carbonate platforms, where interglacials are linked to the development of ooids, peloids, and aragonite mud while glacials are rich in bioclasts (e.g. Bahamas). Until recently the study of this unusual trend was limited to seafloor sediments. Here we present core data retrieved from the upper 13 meters of IODP Site U1461, which represents the sedimentary evolution of the NWS during the last ~15 thousand years.

Sediments which have formed between 15 and 10 ka (i.e. glacial) are predominantly aragonitic. They comprise of small acicular needles, peloids, and ooids. These sediments developed in an arid environment where high alkalinities favored the inorganic precipitation of carbonates. At around 10 ka the NWS underwent a substantial change towards a humid climate accompanied by elevated fluvial influx. These changes are expressed as a shelf wide cessation of inorganic aragonite production. Sedimentation is instead dominated by calcitic bioclasts.

This example from NW Australia displays the importance of climate on the development of shelf carbonates. It further demonstrates that shallow-water aragonite-rich sediments are not necessarily linked to sea-level highstands. We thereby set precedent for the interpretation of similar carbonate systems found within the geological record.

ICDP

Sediment core analyses from ICDP TDP Site 2, Lake Towuti (Indonesia): Characterization of mass movement deposits today and in the past - which information can we gain for other (lake) sediment studies?

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Within the scope of the ICDP-TDP field campaign in May 2015, funded by the DFG project grant no. ME 1169/26, (i) a set of 84 lake surface sediment samples, being distributed over the entirety of Lake Towuti, Indonesia, was taken by grab sampler (UWITEC Corp., Austria) and (ii) ~1018 m of sediment drill core (Russell et al. 2016) were obtained. All samples were investigated equally for physical, chemical, mineralogical, and biological proxies, in order to compare the sample information of the modern sedimentary processes under known environmental conditions, with those of the past ~650,000 years. The results of the surface sediment study support the interpretation of the depositional history (ICDP drill core samples) in dependence on the past climatic and environmental conditions (Hasberg et al. 2018, Morlock et al. 2018, Sheppard et al. in review).

Tropical but ultraoligotrophic Lake Towuti is of tectonic origin and situated on Sulawesi Island (southeastern Indonesia) within the Indo-Pacific Warm Pool. Most of Lake Towuti´s catchment area consists of ultramafic to mafic bedrock, namely of the East Sulawesi Ophiolites complex. The ophiolites around Lake Towuti are composed of gabbros, dolerites, and basalts, as well as serpentinized peridotite (Lherzolite), and unserpentinized peridotites (harzburgite, dunite). The peridotites are intensely weathered to thick laterites, dominated by nickeliferrous oxisol soils. Additionally, the ophiolite is inter-thrusted by the Wasuponda Melange to the northwest, which consists of peridotites as well as sedimentary rocks, and metasediments to the east. The geological settings of Towuti region is poorly known so far but the results of the surface sediment study assume that a further, detailed mapping of the region might shed new light on the bedrock geology in the lake´s catchment and support the previous presumptions. A geological mapping campaign followed by complex sedimentological, geochemical, and mineralogical analyses on rock samples is planned to be conducted in April 2019, with funding from the University of Cologne, aiming on the publication of a revised map of the Malili Region that would support the paleoenvironmental interpretations of a large part of the ICDP TDP community.

Our investigations of the TDP Site 2, which is located in the northern basin of Lake Towuti proximal to the Mahalona River Delta area, focus on the development of the lake, especially on the reconstruction of the hydrological history. The 136.36 m long composite record in the upper 60 m is dominated by mass-movement deposits (Fig. 1), which mainly originate from the Mahalona Delta. A better understanding of the former mass

movement processes is expected from a comparison with a recent mass movement deposit, which was triggered by an earthquake (28. September 2018) and is planned to be also sampled on the field campaign in April 2019.

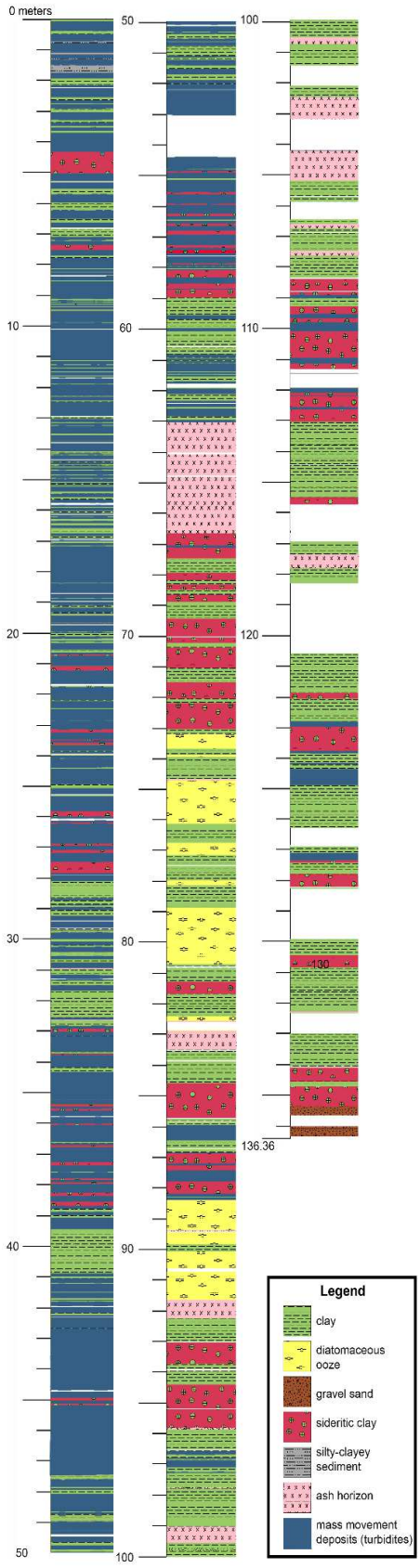

Figure 1: Lithostratigraphic column of the composite profile of ICDP TDP Site 2 located with the Mahalona River Delta area

Here, we present high-resolution (2 mm) XRF data of ~230 m archive core halves of the composite sediments from TDP Site 2 (Fig. 1). Furthermore, mineralogical, sedimentological, geochemical, and biochemical data from ~620 subsamples taken at LacCore in 2016 are presented. The measurement settings were established within the scope of the surface sediment analyses (Hasberg et al. 2018). In addition, 18 thin sections from different sediment horizons throughout the entire composite core were analyzed and. bulk sediment mineralogical analyses as well as spectroscopical measurement (ADS and FTIRS) were carried out on 500 subsamples during a research stay at the Brown University, RI (USA).

The analytical data obtained were analyzed by statistical techniques, e.g. Principle Component Analysis (PCA) using the Excel software add-in XLSTAT, end endmember models were calculated using the Matlab software package 'AnalySize'. Here, we present chemical and mineralogical EM models (EMchem and EMmin) as well as a PCA of the samples. These data represent the sedimentation nowadays, which is dominated by fluvial input with three distinctly different compositions, supplied from five source areas: (i) the Mahalona River, (ii) the Timampu Rivers, (iii) the Loeha River, (iv) steep slopes in the northeast and (v) slopes in the southwest as well as the southern inlets around the Lengke River. The upper ~60 m of the TDP Site 2 composite profile contain >500 mass-movement deposits (Fig. 1).

First geochemical data compared with the surface sediment endmember modelling suggests potential source areas combined with different triggering processes: (i) the Mahalona River Delta – lake-internal slope failure of the delta, (ii) Loeha River (K/Ti curve) input, and (ii) slope failure (Ni/Ti curve) at the north-eastern part of Lake Towuti shoreline. Furthermore, the sharp boundary in all data at ca. 61 m core depth (Fig. 1), corresponding with 121,000 yr B.P, suggests the onset of the Mahalona River flow into Lake Towuti.

IODP

Open Ocean Antarctic Intermediate Water Variability

ED HATHORNE, MARTIN FRANK

GEOMAR Kiel, Germany

As part of the thermohaline circulation Antarctic Intermediate Water (AAIW) redistributes heat and salt but also ventilates the intermediate depths and transports nutrients from the Southern Ocean (SO) to the nutrient deprived tropics. AAIW is therefore of global importance to biogeochemistry and carbon cycling. AAIW formation is intrinsically tied to Circumpolar Deep Water (CDW) upwelling in the SO and is modulated by westerly winds and a seasonal freshening related to sea ice export and melt. Such a strong dependance on seasonal changes in surface ocean conditions makes AAIW formation sensitive to a range of climate modes including ENSO and orbital forcing. Even though it is clear AAIW transport and composition played an important role in the last deglaciation there are very few longer records of AAIW variability. Proxy records of AAIW variability have often provided conflicting views of changes in AAIW strength although a consensus has started to emerge in the relatively data rich Atlantic of a persistent, if slightly weaker AAIW during the last glacial maximum. Neodymium isotope records that suggested greater and more rapid variability have been shown to be biased by sedimentary overprinting which is a problem inherent to the continental shelf settings where most AAIW depth cores are recovered.

To avoid potential sedimentary overprinting and to provide a longer term understanding of AAIW variability we propose a new study utilising intermediate water depth drill cores from open ocean locations in the South Atlantic (DSDP Site 516), the SE Pacific (ODP Site 1236) and the Tasman Sea (DSDP Site 592 and IODP Site U1510). Although the sedimentation rates at these locations are low, the sediments have remained oxic which allows a new water mass proxy of rare earth element patterns to be employed. This will complement benthic foraminiferal stable C & O isotopes and trace metals proxies for temperature (Mg/Ca, Li/Mg) and nutrient content (Cd/Ca, Ba/Ca), and mixed foraminiferal coating Nd isotopes. These tools will generate records of AAIW water mass sourcing, nutrient content and temperature, spanning approximately the last 1.5 million years and covering the important mid Pleistocene transition (MPT). After a high resolution benthic isotope stratigraphy is established at each site, samples spanning key glacial and interglacial intervals from before, during and after the MTP will be analysed for all proxies. Taken together, these records from different basins will provide insights into the role of AAIW in glacial terminations connecting the Southern Ocean with the low latitudes and how ocean circulation responded to orbital and increasing ice sheet forcing during the Pleistocene.

IODP

IODP Site U1517: Insights from hydrocarbon measurements into the gas-hydrate bearing slope sediments at the Toaheni Landslide Complex (TLC) offshore New Zealand.

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2) University of Auckland, Auckland, New Zealand
3) Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover, Germany
4) Oregon State University, Corvallis, Oregon, USA
5) University of Florida, Gainesville, Florida, USA
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7) National Institute of Water & Atmospheric Research Ltd (NIWA), Wellington, New Zealand
8) IODP, Texas A&M University, College Station, Texas, USA

IODP Expedition 372 drilled into the extensional part of the Tuaheni Landslide Complex (TLC) on the Hikurangi Margin offshore New Zealand. The drill site was selected to investigate the potential impact of a gas hydrate system on the slowly creeping masses of the TLC. Hole U1517C was drilled to188 mbsf passing through the base of the slide mass at shallower depth and the BSR just above the base of the hole. Chlorinity measurements and logging while drilling (LWD) data show the occurrence of gas hydrates at roughly 105 – 160 mbsf. The hydrocarbon system was examined by measuring composition and isotopic signatures of methane (C1) to butane (C4) on void gases and hydrate-bearing sediments.

The C1/C2 ratios and isotopic signatures show a biogenic origin of methane at all depths. Propane concentrations are low and the depth profile shows a clear separation of C2 and C3 maxima based on the exclusion of propane from structure sI gas hydrates. The C2/C3 ratio therefore allows refining the depth distribution of gas hydrates at the TLC site. The comparably heavy isotopic $\delta^{13}C$-C_3H_8 value indicates a residual signature. Considering the hydrocarbon distribution and isotopic signatures there is no indication of a recent gas pulse and as such no suggestion for a possible influence of the gas hydrate system on the creeping part of the TLC site via the pressure valve hypothesis (Mountjoy et al., 2014). The proposed mechanism is based on the release and transmission of free gas pulses from below the gas hydrate-bearing zone by hydro fracturing.

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ICDP

Boreal forest bi-stability around Lake El'gygytgyn (NE Russia) during interglacial of the last 2.15 Million years

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The project aims to answer the timely questions "Why is northern Asia dominated by larch forests?". Our overall hypothesis is that summergreen and evergreenneedle-leaf forests represent alternative quasi-stable states that can occur under similar climate conditions during interglacials of the last 2.15 Myr, being triggered by different environmental conditions and the composition of northern tree refugia during the preceding glacials.

The stated hypothesis requires the setup and sophisticated analyses of palaeoenvironmental data sets, in particular, palaeovegetation sequences need to be related to vegetationindependentclimate data to assess lagged relationships. Vegetation-climate relationships will be investigated on two different time-scales: Changes on glacial/interglacial times-scale (requiring an ~2-5 ka resolution) will be assessed for the entire period of the last 2.15 Myrs while millennial scale changes (requiring an ~0.5-1 ka resolution) will be only assessed forselected glacial/interglacial cycles. Suitable candidate key cycles are MIS 58 (cold?)/MIS 57 vs. MIS 56 (warm?)/MIS55, MIS32(warm?)/MIS 31, MIS26(cold?)/MIS25, MIS10(cold?)/MIS11, MIS6(cold)/MIS5), MIS2(cold)/MIS1 as they seemingly have contrasting glacial conditions. However, selection will be refined by a detailed investigation of all available proxy-data. Pollen data (validated by sedimentary ancient DNA results for selected glacial/interglacial cycles) as proxy for past vegetation change will be numerically related to palaeoclimate data i.e. δ18Odiatoms for selected key glacial/interglacial cycles and selected records marine palaeo records covering the entire 2.15 Myrs. The project only started by the beginning of 2019, so first results are expected by summer 2019.

ICDP

The Lomati water tunnel, a perfect complement to the BASE Drilling Program (Paleoarchean, Barberton Greenstone Belt, South Africa)

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Institut für Geowissenschaften, Friedrich-Schiller Universität Jena

The 2880 m long Lomati water tunnel traverses the two facing, subvertically dipping fold limbs of the Saddleback Syncline in the Barberton Greenstone Belt, exposing volcanic and siliciclastic strata of the Moodies Group (~3224 – ~3218 Ma) of about 1000 m thickness each. This unit represents some of the world's oldest well-preserved tidal, deltaic and terrestrial strata and bears global significance. Key strata are currently targeted by an ICDP full proposal (resubmitted January 2019) because they uniquely constrain multiple Paleoarchean environmental parameters.

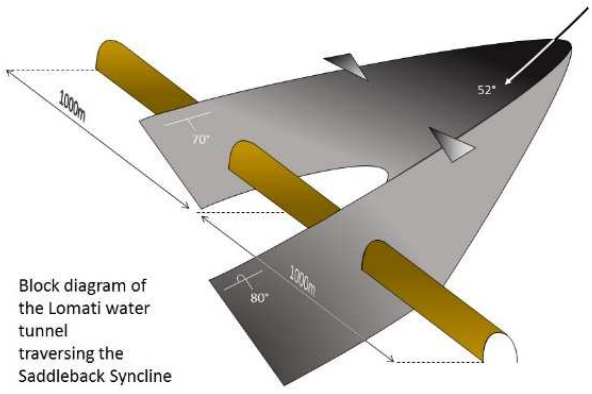

Figure 1: Block diagramm

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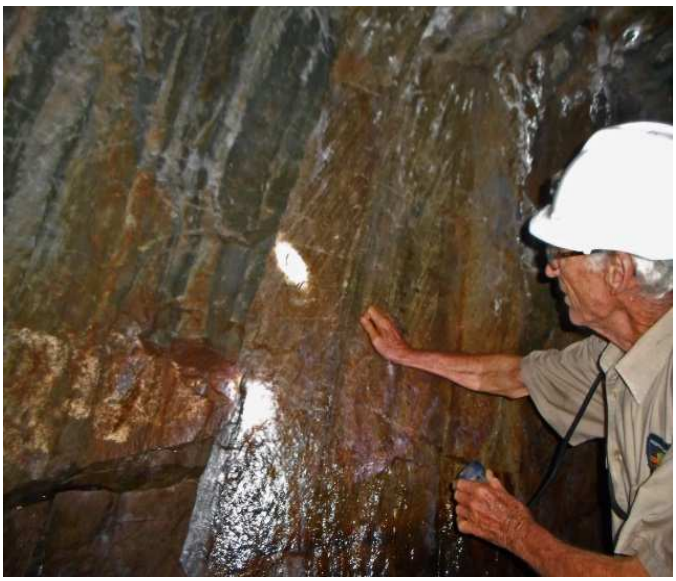

Figure 3: Steeply dipping cross-bedded sandstones interbedded with grey shales; likely a tidal facies

IODP

Late Miocene evolution of the Australian Monsoon: New sediment archives from IODP Expedition 363 - Western Pacific Warm Pool

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The exceptional setting of the Australian Monsoon (AM) subsystem at the southern edge of the largest amplitude seasonal swing of the Intertropical Convergence Zone (ITCZ) within the large-scale Asian-Australian monsoon system makes it a highly sensitive monitor of tropical hydroclimate variability. However, the long-term development of the AM and its linkages to high-latitude climate evolution remain highly enigmatic, largely due to the scarcity of records from this strategic region. In particular, the evolution of the AM during warmer periods of Earth's climate history with higher atmospheric pCO_2 levels and without extensive Northern Hemisphere glaciations, which provide a potential analog of future conditions on Earth, is virtually unexplored. During IODP Expedition 363, an extended (sedimentation rate: ~6 cm/kyr), undisturbed upper Miocene to lower Pliocene hemipelagic succession was retrieved off NW Australia (Site U1482, 15°3.32′S, 120°26.10′E, water depth: 1466 m). This outstanding sediment archive provides a first complete, high-resolution record of AM variability from ~10.7 to 4.3 Ma. Here, we present initial results from oxygen ($\delta^{18}O$) and carbon ($\delta^{13}C$) isotope analyses of benthic foraminifers combined with XRF-scanning terrigenous runoff and grain size proxy data. These new records reveal that a strong monsoonal regime prevailed during a period of global cooling and drying from ~7 to 5.5 Ma (Herbert et al., 2016; Holbourn et al., 2018). Monsoonal precipitation and runoff were paced by precessional insolation forcing, whereas the $\delta^{18}O$ and $\delta^{13}C$ records exhibit a marked response to obliquity. A massive intensification in monsoonal runoff from NW Australia occurred from ~5 to 4.4 Ma during an interval of global warmth. A direct comparison to new high resolution records of the Indian Monsoon (IODP Expedition 353, Sites U1447-U1448) will provide new insights into the phase relationships between Southern and Northern Hemisphere monsoonal subsystems. Ultimately, our project will contribute to the overarching question of whether monsoonal systems are mainly forced by local insolation of adjacent landmasses or by changes in global boundary conditions such as ice volume and latitudinal or zonal temperature gradients.

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IODP

Boron and Lithium isotope geochemistry of pore waters in subduction inputs to the Sumatra subduction zone

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Fluids are the agent for geochemical reactions and thus the study of pore water geochemistry is an important tool to constrain water-rock interactions. At subduction zone forearcs fluids that have travelled from the inner forearc to the seafloor are often exotic in their composition and commonly reflect sediment diagenetic processes at depth. Because these processes promote lithification and induration of sediments their spatio-temporal occurrence plays a crucial role for the mechanical behavior of subduction zone sediments. Recent studies suggest that the altered oceanic crust plays also an important role in shallow hydro-mechanical processes. The alteration state of the incoming oceanic crust therefore may have crucial implications for mechanical and fluid flow processes in the subduction zone forearc. Because sediment lithostratigraphy and thermal structure vary worldwide the fluid-rock interaction processes must be characterized individually for each subduction zone.

We investigated the composition of pore fluids sampled from a ~1430 m thick sediment succession on the Indo-Australian plate offshore N Sumatra that provides the protolith of the Sumatra subduction zone where on December 26 in 2004 the Mw ~9.2 Sumatra-Andaman earthquake nucleated and caused a devastating tsunami. Shipboard measurements revealed that the geochemical profiles at Site U1480 reflect the combined effects of organic matter diagenesis, alteration of volcanogenic sediment, and reactions in oceanic basement. To gain a more detailed insight into the key water-rock and hydrogeological processes, we analyzed the B and Li isotope composition of the pore fluids from the seafloor to 1300 mbsf.

Post-cruise re-analyses of B concentrations decrease from seawater value (416 µM) at the seafloor to 159 µM at 1400 mbsf (meters below seafloor) with a stronger decrease in the upper 400 mbsf. The trend is not continuous but interrupted at 74 and 1241 mbsf towards higher and at 369 mbsf towards lower concentrations. The B isotopic composition broadly mimics the B concentration profile showing elevated $\delta^{11}B$ values at 74 and 1241 mbsf. B isotope composition ranges from 36.2 to 45.5‰ with most values being higher than seawater from net uptake of ^{10}B. Li concentrations decrease in the shallow (>100m) subseafloor from seawater value to ~5 µM. Below that depth Li increases to 20 µM at 1065 mbsf. The increase is not continuous but shows several minima and maxima. The cause for the cyclicality is yet unknown and will be investigated by further compositional analysis of the solid phase to shed light on a lithological dependency. Below 1115 mbsf Li concentrations increase continuously to 380 at 1300 mbsf. The Li isotopic composition ranges from 15.5 to 26.6‰ and broadly mimics the Li concentration profile. In the shallow subseafloor $\delta^{7}Li$ values decrease to a value of 15.5‰ at 215 mbsf, which is followed by an increase to 26‰ at 1214 mbsf. Below that depth the Li isotopic composition decreases to 14‰ at 1392 mbsf. Preliminary assessment of both B and Li systematics corroborates the assumption that alteration of sedimentary volcaniclastics plays a dominant role in in the upper 1250 mbsf, which corresponds to Nicobar fan sediments. In the underlying pelagic section B and Li concentrations indicate a diffusional contact of the pore fluid to the oceanic crust. This is consistent with high $\delta^{11}B$ values indicating that the residual fluid from the low temperature alteration process is the endmember. On the other hand, high Li concentrations and low $\delta^{7}Li$ values point to hydrothermal conditions – probably related to igneous intrusions that are present in the pelagic section. A more detailed assessment of the B and Li systematics will shed light on this conundrum and thus provide

a better understanding of the alteration history of the incoming oceanic crust, which is crucial for predicting the alteration state at the trench of the Sumatra subduction zone.

IODP

Sea-level change across the Plio-Pleistocene intensification of Northern Hemisphere Glaciation: Reconciling signals from the Eastern Equatorial Pacific and the North Atlantic

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With the drastically increasing manifestation of anthropogenic forcing on Earth's climate, understanding and quantifying the response of sea level/ice volume to global warming is instrumental for the current discussion on adaptation and mitigation measures (e.g., IPCC, 2014; Nicholls et al., 2014). To improve our understanding of ice-sheet/sea-level behavior, high-fidelity and temporally highly resolved sea-level records associated with climate variability of warmer-than-modern periods of Earth's history (i.e., >500 kyr) are required. Yet, such records are sparse, exhibit inconsistencies with one another, and/or are typically of low temporal resolution. Temporally highly resolved information on sea-level variability for past intervals with similar climatic boundary conditions to those of the near future are, however, an indispensable prerequisite to (i) understand and predict near-future sea-level change more accurately, and, ultimately, to (ii) identify the mechanisms underlying the behavior of ice sheets under warmer-than-modern climates by comparing them to the well-known ice-sheet dynamics of the late Pleistocene (e.g., Rohling et al., 2007; Walbroeck et al., 2002).

Here we present new, millennial-scale deep-sea temperature and inferred sea-level records based on benthic foraminiferal (Oridorsalis umbonatus) oxygen-isotope and Mg/Ca data from the Eastern Equatorial Pacific (ODP Site 849). Our study interval from ~2.65 to 2.4 Ma (Marine Isotope Stages [MIS] G1–95) includes the culmination of the late Pliocene to early Pleistocene intensification of Northern Hemisphere Glaciation (iNHG) when large-scale ice sheets in the Northern Hemisphere were first established (e.g., Bailey et al., 2013; Balco & Rovey, 2010). The most salient features of our study are as follows:

(i) Deep-sea temperatures at East Pacific Site 849 were between ~0 and 3°C across the studied time period, with small-amplitude glacial-interglacial oscillations of only <2°C. Comparison of deep-sea temperatures from the East Pacific (Site 849) and the North Atlantic (IODP Site U1313) allows us to unravel the history of glacial-interglacial water-mass changes in the deep North Atlantic at a much higher temporal resolution than so far available (compare Lang et al., 2016). Percentages of water-masses that we reconstruct provide a promising new avenue towards an accurate deep-water mass correction of sea-level records generated from sediment cores of the North Atlantic realm.

(ii) Absolute sea-level values as reconstructed from our data fluctuate between ~54 m above and ~37 m below modern levels. The iNHG is clearly documented in our data by an increase in the amplitude of glacial-interglacial sea-level change from ~35 m prior to MIS 100 to ~50 m afterwards. In contrast to previous studies (e.g., deBoer et al., 2014; Rohling et al., 2014; Bintanja and Van de Wal, 2008) we find that the iNHG was associated with lower sea levels and increased ice volume during interglacials as well as glacials from MIS 100 relative to the latest Pliocene values.

(iii) Sea-level structures identified for MIS 100 (~2.52 Ma) and 96 (~2.43 Ma) in the East Pacific (Site 849) and the North Atlantic (Site U1313) are strikingly reminiscent of those reported for late Pleistocene glacials using different methods (e.g., Elderfield et al., 2012; Rohling et al., 2007; Walbroeck et al., 2002). They exhibit a "sawtooth"-like structure with rapid deglaciations and a final sea-level drop before the termination. This implies a similar mechanistic behavior of early and late Pleistocene ice sheets. We thus hypothesize that MIS 100 and 96 possibly were early attempts of Earth's climate to shift into the asymmetric glacial-interglacial cyclicity of global sea-level/ice-volume change of the late Pleistocene as it was finally established ~1.5 Myr later.

Our detailed records add to a growing body of work to better understand global sea-level/ice-volume change under warmer-than-modern climate boundary conditions. They therefore have important implications for sea-level predictions in a future greenhouse world. In this context, we are currently generating millennial-scale-resolution sea-level data for East Pacific Site 849 covering a much longer time period (~3.35–2.05 Ma) than the one studied above (~2.65–2.4 Ma). This interval comprises the full range of climatic conditions relevant for understanding near-future climate change. To achieve a sea-level record with unprecedented accuracy, we will further test the fidelity of the Mg/Ca-based temperature component extracted from oxygen isotopes to yield sea-level via clumped-isotopes thermometry applied to benthic foraminifera of the same samples.

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ICDP

Integrating neontology and paleontology to unravel the evolution of diatoms in the East African Rift lakes

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The East African Rift lakes are among the world's most renowned hotspots of biodiversity. Multicellular organisms within the rift evolved mainly via in situ speciation. By contrast, the evolutionary history of unicellular eukaryotic organisms such as diatoms in these lakes remains largely unknown. Here, we used the genus Afrocymbella endemic to the East African Rift lakes as a model taxon to test pattern and processes of evolution in diatoms over time.

We implemented an integrative framework that combines both molecular information derived from extant species and fossil information obtained from lake sediments. By using a fossil time-calibrated multi-locus phylogeny, we found that Afrocymbella is monophyletic and most likely evolved within the rift system (MRCA mean stem age: 15.16 Ma, 95% highest posterior density, HPD: 7.61, 23.85). Intrageneric relationships suggest potentially distinct clades for the species of Lake Challa and Lake Malawi, which have evolved 0.40 Ma (MRCA crown age) and 0.81 Ma, respectively.

In a second step, we used fossils from the sediment record of Lake Malawi to independently estimate the timing of speciation for some Afrocymbella species. The first appearance of endemic species in the core roughly coincides with the estimated age of the MRCA, even when we account for preservation bias. Although molecular and fossil data both indicate that Afrocymbella evolved in situ within the rift, the underlying

mechanisms remain unknown. Therefore, future work will focus on examining whether the speciation events were triggered by major climate and environmental events by utilizing information from the sediment records of lakes Malawi and Challa.

Our study is among the first to combine molecular, paleontological, and environmental data with the aim to infer evolutionary patterns and processes in diatoms throughout the East African rift. Moreover, the approach strengthens recent findings that in situ speciation is most likely a relevant mechanism in promoting endemic diatom diversity in isolated environments such as ancient lakes.

ICDP

Tracing sediment provenance and hydrological balance in the Levant during the Holocene using geochemical fingerprints

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Laminated lacustrine sedimentary sequences in the Dead Sea basin offer a unique chronological constrain on rapid climatic events in the Levant during the Holocene and beyond. This extreme environment is highly sensitive to climate-induced environmental changes recording the regional palaeo-hydrological history. Within the project PRO-HYDRO, we aim to reconstruct the provenance of detrital and authigenic sediments across the Dead Sea basin and the ICDP site 5017-1. In order to understand the contribution of different distributaries to the ICDP site, we will compare the radiogenic isotope signatures in the Levant basin, including the western (Ein Gedi, Ein Feshkha) and the eastern Dead Sea (Jordanian part of the catchment from which no data is available thus far). Down-core sampling spanning the past 20 ka will, on the other hand, bring new insights into periods of abrupt climate change (e.g. early Holocene). The unique geochemical behaviour of the Sm/Nd and Rb/Sr isotope systems provides a powerful tool for studying spatio-temporal source dynamics of sediment deposits. While Nd isotope ratios (εNd) approximate the time of extraction from the mantle, Sr isotopes ($\delta^{87/86}$Sr) are strongly affected by chemical weathering and geological process, giving the contributed sediment a characteristic chemical signal. The marked geological contrasts across the Dead Sea basin (e.g. young basalts in the north vs. older crystalline rocks or sediments in the south) make it a well-suited area for paired Nd-Sr fingerprinting. Furthermore, separation of the various fractions present in the Dead Sea sediments (salts, carbonates, authigenic coatings and detrital residue) will allow for discriminating between specific environmental processes. In this contribution we present our analytical setup and recent developments for a reliable extraction of Nd and Sr signals from the Dead Sea sediments that will be employed for deriving a highly resolved record of past climatic oscillations.

IODP

Pleistocene East African terrestrial environmental conditions and reduced glacial NADW flow in the northern Mozambique Channel (IODP Site U1476)

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Terrigenous marine sediment cores are often regarded as archives of paleoclimatic conditions on land. At the same time sediment sources and transport routes change over time and may overprint the primary terrestrial climate signal. It is thus important to unravel paleoceanographic and paleoclimatic processes. During IODP Expedition 361 - SAFARI six sites were drilled in the SW Indian Ocean to reveal paleoceanographic and paleoclimatic change throughout the Plio/Pleistocene. Site U1476, located in the northern Mozambique Basin at the same latitude as Lake Malawi, offers an exceptional opportunity to disentangle past variability and connections between the terrestrial climate in East Africa, sediment transport mechanisms and regional hydrography. Magnetic properties and scanning XRF data from Site U1476 reveal the establishment of a pronounced glacial-interglacial variability after the Mid Pleistocene Transition (MPT). During interglacials the concentration of terrigenous sediment increases, while it is strongly diluted by marine carbonate during glacial periods. Two major terrigenous sediment sources are suggested by end-member unmixing techniques. First, Zambezi riverine sediment, which is transported by northward flowing North Atlantic Deep Water (NADW), forms the major component of the terrigenous sediment fraction. The changes in abundance of Zambezi riverine sediment are consistent with phases of increased fluvial input during humid interglacial and dry glacial conditions in East Africa, in accordance to records from Lake Malawi. The second terrigenous end-member shows only weak glacial-interglacial variability throughout the 1.25 Ma long record, but its abundance shows a marked increase after ca. 250 ka. As this period coincides with the onset of megadroughts at Lake Malawi, we propose that this end-member signifies the establishment of dry conditions in East Africa. It may either represent aeolian material or a change of composition of Zambezi material due to less intense chemical weathering. Apart from these continental derived climate signals, the strong resemblance of terrigenous sediment supply with the co registered Site U1476 benthic stable isotope data implies that oceanographic transport processes might also enhance the glacial-interglacial variability. For example it is possible that the northward advection of Zambezi sourced terrigenous material was reduced during weakened northward flow of NADW in glacial times. The imprint of variability of NADW on sediments at Site U1476 is revealed by punctuated magnetite dissolution events during MPT glacials, which have been described as phases of low NADW production. During these extreme conditions, bottom waters (NADW) bathing Site U1476 were either strongly depleted in oxygen or even replaced by a oxygen-poor water mass, inducing reductive conditions and magnetite dissolution in the sediment.

ICDP

Methanogenesis dominates organic matter mineralization in modern ferruginous sediments

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Organic matter mineralization and diagenesis in ferruginous (Fe-rich) sediments likely played a key role in global biogeochemical cycling during much of the Archaean and Proterozoic eons. Knowledge of organic matter mineralization in ferruginous sediments, however, remains almost entirely conceptual, as analogous modern sediments are extremely rare and largely unstudied. We recovered modern ferruginous sediments from Lake Towuti, Indonesia, and used a suite of biogeochemical analyses to assess rates and pathways of organic matter mineralization. Here we show that organic matter

mineralization in these sediments is almost exclusively channeled through methanogenesis despite an abundance of ferric iron minerals known to support microbial respiration in laboratory experiments. The tendency towards methanogenesis in these very iron-rich modern sediments implies that this process may have played a very important role in organic matter mineralization in Precambrian time and thus could have been a key contributor to Earth's early climate dynamics.

ICDP

Core-log-seismic data integration to improve the seismic stratigraphy within the ICDP drilling project COSC-1, Sweden: challenges and first results

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Based on the ICDP priority program "Collisional Orogeny in the Scandinavian Caledonides (COSC)", we integrate and link geophysical properties from laboratory investigations, borehole measurements, and reflection seismic data from the COSC-1 drilling project in the western Scandinavian Caledonides. The aim is to construct an improved seismic stratigraphy along the 2.5 km-deep and fully cored COSC-1 borehole, which was drilled in 2014 into the lower Seve Nappe Complex to better understand the deep orogenic processes in mountain belts.

By using synthetic seismograms from borehole logs and matching them to 2D and 3D seismic data, we can identify lithological boundaries that represent seismic reflectors and correlate them with changes in acoustic impedance. In terms of mineralogy, these reflections correspond to interfaces between mafic and felsic rock units but also to the mineral structure and microstructure. We compared P-wave velocity data measured on core with a multi-sensor core logger with those obtained under in-situ conditions from a downhole sonic log. Initially, we attributed the distinct differences in P-wave velocities between these two data sets to the direction of the P-wave measurement (either horizontal or vertical) and the different measurement conditions (laboratory or in situ). In the next step we measured seismic velocities and anisotropy on selected core samples under pressure conditions that are comparable to in-situ pressure, which in turn better explain the P-wave velocities measured downhole. This indicates that velocity differences between multi-sensor core log and downhole log data are likely caused by the formation of microcracks. We will now link mineralogical, compositional and structural information of the selected core samples with their geophysical properties to determine the different seismic facies units.

So far, our investigations show that there are two main challenges when attempting core-log-seismic data integration in a metamorphic setting. Firstly, the cores are strongly affected by depressurization and excavation damage caused by drilling. Therefore, multi-sensor core logs at ambient pressure and temperature conditions are a poor proxy for in-situ seismic properties, which complicates the correlation of core and borehole logs. Secondly, the high seismic velocities (>5 km/s) at shallow depths and their strong variability lead to poor seismic imaging compared to sedimentary basins in the marine environment. Consequently, additional seismic processing efforts are necessary for a successful core-log-seismic data integration.

ICDP

Application of XRF core scanning to peat and other organic-rich sediments

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X-ray fluorescence core scanning (XRF-CS) has become a standard tool in paleoenvironmental studies. Allowing rapid, inexpensive and non-destructive analysis of the elemental composition of sediment cores at very high spatial resolution, it is ideally suited for the reconstruction of short-term climatic change. For the Quaternary of the terrestrial realm, peat deposits are arguably one of the most important archives preserving environmental signals. Traditionally mostly exploited by palynological studies, they allow climate reconstructions across a wide range of geographical settings – from the tropics to polar latitudes and from sea level to high-alpine altitudes. Among such peat deposits, records from ombrotrophic peat bogs play a special role because the input of minerogenic components is exclusively through atmospheric transport. However, the applicability of XRF-CS to cores that consist of peat and other highly organic-rich sediments has yet remained poorly explored. The extremely high organic matter and water content of such sediments render it difficult to reliably detect the low-concentration elemental composition of the minerogenic fraction. This is because both organic matter and water consist predominantly of elements with atomic numbers ≤12 that effectively dilute the minerogenic matter. In addition, these light elements can absorb parts of the radiation emitted by heavier atoms before it reaches the detector of the scanner.

Considering these shortcomings, we have investigated the application of XRF-CS to two peat cores of Late Glacial–Holocene and Eemian age from the Füramoos peat bog, Southern Germany, using an Avaatech 4th generation XRF core scanner. The Glacial–Holocene core consists of ombrotrophic peat with an organic content >90 %; the Eemian core is made up of fen peat and organic-rich muds with organic contents between 30 and 79 %.

The XRF-CS-derived distributions of elements widely used in paleoclimatic studies (i.e., Al, Ca, Fe, K, Mg, Mn, S, Si, and Ti) were systematically compared to autoclave-assisted, acid-digested inductively coupled plasma optical emission spectrometry (ICP-OES) measurements. For the Late Glacial–Holocene core, we find that XRF-CS yields reliable semi-quantitative data for the majority of the investigated elements (i.e., Ca, Fe, K, Mn, S, Si, and Ti), with $R^2 \geq 0.5$. XRF-CS-derived signals for Al and Mg, however, were consistently unreliable due to their relatively low concentrations in the peat (mostly <2,000 ppm for Al and <1,000 ppm for Mg) and the generally relatively high detection limit of XRF-CS for light elements (2,000 ppm and 10,000 ppm for Al and Mg, respectively). XRF-CS of the fen peat and organic-rich muds from the Eemian at Füramoos yields similar results as for ombrotrophic peat. Reliable semiquantitative data emerged for Al, Fe, K, S, and Ti ($R^2 \geq 0.5$) and, to a lesser extent, for Si ($R^2 = 0.233$). Similar to the ombrotrophic peat, Mg concentrations in the fen peat and organic-rich muds (<5,000 ppm) were too low to yield reliable data. For yet unknown reasons, the XRF-CS-derived results of Ca and Mn from the Eemian do not correlate with the ICP-OES data, despite elemental concentrations well above the detection limits. In summary, our study indicates that XRF-CS allows to semi-quantitatively reconstruct the distribution of the majority of paleoclimatically relevant elements in peat and other highly organic-rich sediments. Considering its straightforward application and relatively low cost, XRF-CS is therefore well suited to complement the analytical toolbox for the paleoenvironmental and paleoclimatic study of such sediments.

ICDP

Investigation of the fractal dimension of cataclasites in target rocks of the Chicxulub impact crater (Mexico) using SAGA GIS image analysis

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The 66 Ma Chicxulub crater located on Yucatán peninsula, Mexico, is one of the best-preserved impact structures on Earth. In addition to the formation of a crater bounding outer ring of about 180 kilometers in diameter, the Chicxulub impact crater developed a shallow internal ring with a diameter of estimated 80 kilometers called the peak ring. IODP/ICDP Expedition 364 drilled the peak ring in 2016 and recovered a drill core with an impactite unit of about 800 meters after removal of the overlaying post impact-sedimentary rocks. It mainly consists of fractured granitoid target rocks with local occurring cataclasites, which are classified depending on their amount of matrix in cataclasites and ultracataclasites.

The mechanism behind the formation of the peak ring is not even known in detail. Large-scale impact craters with comparatively low depths require a temporary occurrence of reduced friction in rocks to cover wide distances in short time. Considering that, three models are under discussion, these are acoustic fluidization, meaning a weakening of rock caused by vibrations,

thermal softening or strain rate weakening/frictional melting. Analysis of local occurring different cataclasites is used to clarify whether they were gradually or independently formed and might in consequence give a line on the formation of the peak ring. The question arises, whether the analytical results for the cataclasites allow a classification into the mentioned two classes. Similarities within our collected fractal dimension and some values out of other publications will also be examined. Moreover, we will investigate whether there is an obvious gap between the categories. If so, evidence of an independently development of both cataclasites is given, because otherwise existence of gradations is necessary. To get conclusions about transport distances and directions we will also figure out the deviation of mineral grains in terms of sphericity and the existence of shaped-preferred orientations.

The fractal dimension of both types of cataclasites is quantified in several thin sections viewed under a polarization microscope. Analysis is done by using a semi-automatic image segmentation workflow based on an automated seeded region growing algorithm which is implemented in the open-source Geographic Information System (GIS) software SAGA GIS. Polygonization of the grain fabric is based on spectral information of individual mineral phases and optically distinguishes different mineral phases to allow quantitative information on the two categories of cataclasites. The limited resolution of the thin sections requires a development in the regular workflow by implementing new tools to yield more precise results. The determined fractal dimension displays higher values in ultracataclasites than in cataclasites. However, both types show similarities in terms of sphericity. Orientation is missed in cataclasites but occurs in ultracataclasites in almost half the samples. Results seem to point out to an existing gradual formation of cataclasites because there is no obvious boundary detected between the two types. In conclusion, SAGA GIS turns out to be a suitable tool for the determination of fractal dimensions of cataclasites.

IODP

Availability of reactive iron for microbial iron reduction and assessment of the diagenetic overprint of sediments within the deep subseafloor biosphere in the Nankai Trough, Japan – IODP Expedition 370

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IODP Expedition 370 (Temperature Limit of the Deep Biosphere off Muroto) established Site C0023 down to 1180 mbsf in the Nankai Trough off Shikoku Island, Japan, to explore the upper temperature limit of microbial life in deep subseafloor sediments. Part of the scientific program is to investigate the availability of nutrients and energy substrates and to identify unique geochemical and microbial signatures that differentiate the biotic and abiotic realms and/or their transitions (Heuer et al., 2017).

Iron (Fe) reduction is considered one of the most ancient forms of microbial respiration (Vargas et al., 1998). In addition, Fe reducers can grow under high temperature and pressure conditions (Kashefi and Lovley, 2003), suggesting that microbes that use Fe oxides as energy substrates are potential candidates to survive close to the temperature limit of the deep biosphere.

In this study, we aim at assessing the role of Fe oxides for microbial respiration and the related diagenetic alterations in deep sediments of Site C0023 by applying sequential extractions of Fe oxide and sulfide minerals. Volcanic ash layers, which are ubiquitous in sediments of Site C0023, are of particular interest as they have been identified earlier as hotspots for microbial life (e.g., Inagaki et al., 2003). Torres et al. (2015) further showed that ash layers at a different site in the Nankai Trough are typically rich in Fe and Mn oxides. Their results support the findings of Treude et al. (2014) who postulate a coupling of microbial processes to mineralogy. In addition, on-board measurements show a release of dissolved Fe into the pore water in the depth interval associated with volcanic ash layers (Heuer et al., 2017), suggesting that the observed liberation of dissolved Fe is related to an alteration of Fe phases in these ash layers.

Our results show that the total Fe content in sediments of Site C0023 is relatively constant at ~4.2 wt%. The reactive Fe oxide content represents 25% of the total Fe. Based on sequential extractions, the fraction associated with amorphous Fe oxide such as ferrihydrite and lepidocrocite is the dominant Fe fraction with ~0.7 wt%. Mineralogical analyses are currently conducted in order to determine specific Fe mineral phases within this fraction. The total Fe contents in the ash layer samples strongly vary between 1.4 and 6.8 wt%. However, most samples generally contain less total Fe than the surrounding sediments. Similarly, the contents of the reactive Fe oxides are significantly lower. Thus, reactive Fe oxides in ash layers at Site C0023 do not seem to represent the energy substrate for microbial Fe reduction. As one of the next steps, stable Fe isotope (δ^{56}Fe) analyses will be performed on (1) pore-water samples, the (2) different Fe oxide phases and (3) sediment residues remaining after sequential extractions in order to trace the source and reaction pathway for the observed release of dissolved Fe into the pore water.

Diagenetic Fe cycling, in particular the reductive dissolution of Fe oxides driven by the reaction with hydrogen sulfide, may lead to the transformation of reactive Fe oxides to Fe sulfides such as pyrite (e.g., Berner 1970). Fe monosulfide contents are below detection limit in sediments of Site C0023. Pyrite, in contrast, occurs over the whole core interval with strongly varying contents. Three significant peaks with contents up to 0.5 wt% could be observed at 552, 707 and 1033 mbsf. The pyrite profile generally mimics the total sulfur profile, which suggests that most of bulk sulfur is present as pyrite. Fe bound in pyrite (Fepyrite), however, only represents less than 5% of the total Fe pool, except for the interval with elevated pyrite contents where Fepyrite accounts for ~10% of bulk Fe. This indicates that sulfidation does not affect the whole Fe oxide pool in sediments of Site C0023. The reductive dissolution of primary ferrimagnetic Fe oxides and the formation of secondary paramagnetic pyrite is generally known to modify rock magnetic properties such as magnetic susceptibility (e.g., Berner, 1970). Thus, our geochemical results are presented in combination with post-cruise generated magnetic susceptibility data. By combining the geochemical methods, including sequential Fe oxide and sulfide extractions and subsequent δ^{56}Fe analyses, with rock magnetic measurements, we intend to decipher the role of Fe mineral phases in maintaining deep subsurface life at Site C0023.

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ICDP

Centennial-scale vegetation dynamics and climate variability in SE Europe during Marine Isotope Stage 12 based on a pollen record from Lake Ohrid

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Characterised by a maximum expansion of continental ice sheets in the Northern Hemisphere, Marine Isotope Stage (MIS) 12 (~478–424 ka before present) was one of the strongest glacials of the Quaternary. Because the information currently available on MIS 12 is predominantly derived from marine records, the imprint of this extreme glaciation on the terrestrial realm – and notably on terrestrial ecosystems – has remained poorly constrained. In

light of the above, we here present a new, centennial-scale-resolution pollen record from Lake Ohrid (SE Europe), and pollen-based quantitative temperature and precipitation estimates. Our results, which span the period from 488 to 420 ka, show that the forest cover around Lake Ohrid decreased substantially over the course of MIS 12. This change was associated with lower winter (MTCO), summer (MTWA) and mean annual temperatures (TANN) as well as lower mean annual precipitation (PANN). Specifically, MTCO, MTWA and TANN reached minimum values of –22, 11 and –4 0C, respectively, at 430–429 ka; in addition, PANN reached a minimum of 240 mm at 455 ka.

Superimposed on this long-term development, abrupt changes in regional forest cover indicate a pronounced millennial-scale climate variability that bears strong resemblance to the Dansgaard-Oeschger (D-O) and Heinrich events of the Last Glacial. The D-O-like variability is expressed by repeated forest expansions around Lake Ohrid during the early and middle parts of MIS 12 (from ~478 to 440 ka). These forest expansions can be correlated to previously documented episodes of surface-water warming in marine records from the North Atlantic, the Iberian Margin and the western Mediterranean Sea. The Heinrich-like events during MIS 12 are evidenced by strong forest contractions around Lake Ohrid. These forest-contraction events can be correlated with pulses of ice-rafted debris deposition in the North Atlantic and Iberian Margin. This pattern indicates a close coupling of climatically forced tree-population changes in SE Europe and the variability of the Atlantic Meridional Ocean Circulation during MIS 12 on millennial timescales.

IODP

Indian Ocean circulation and monsoon variability across late Neogene climate transitions: New insights from intermediate and deep water sediment archives in the Andaman Sea and on the Ninetyeast Ridge

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Late Neogene sediment archives at the margins of the Bay of Bengal and Andaman Sea (IODP Expedition 353, iMonsoon) record Indian Ocean intermediate- and deep-water circulation and Indian Monsoon variability in unprecedented resolution. Site U1443 (2925 m water depth), drilled on the crest of the Ninetyeast Ridge at the southern end of the Bay of Bengal, provided the first high resolution Indian Ocean record of Miocene deep water paleoceanography extending back to 17 Ma. Benthic foraminiferal isotope records in combination with X-ray fluorescence (XRF) scanner elemental data track the abrupt onset and development of the Miocene Climatic Optimum with eccentricity-paced transient carbonate dissolution events coinciding with warmer phases, followed by major expansion of the East Antarctic ice sheet during the middle Miocene Climate Transition. An intense carbonate dissolution episode between ~13.2 and ~8.5 Ma correlates with the "Carbonate Crash", originally identified in the Equatorial Pacific and Caribbean regions, providing new evidence for its global character. The recovery from the "Carbonate Crash" in the tropical eastern Indian Ocean was coupled to a marked increase in biological productivity, which we relate to a strengthening of monsoonal winds and upper ocean mixing.

At Sites U1447 (1392 m water depth) and U1448 (1098 m water depth) in the Andaman Sea, orbitally-tuned, high resolution isotope records and XRF-scanning elemental data, combined with temperature/salinity reconstructions from paired stable isotope and Mg/Ca records closely track changes in the intensity of the Indian summer monsoon rainfall over the interval from 9 to 5 Ma. In addition, these records allow to monitor paleoproductivity changes in response to variations in monsoonal wind patterns over the equatorial Indian Ocean. Sites U1447 and U1448 provide the first complete millennial resolution mixed layer temperature and salinity records in the core area of the Indian Monsoon over the critical interval between 9 and 5 Ma, when major changes in the Indian-Asian-Australian monsoon system occurred. Intense, pulsed cooling of surface and intermediate waters occurred between ~7 and ~5.5 Ma, associated with changes in the composition of the monsoonal discharge from the Asian continent into the Andaman Sea.

IODP

Tephrochronostratigraphy in marine and terrestrial sediments of New Zealand: Benchmark for Miocene to Quaternary explosive volcanism

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During IODP Expeditions 372 and 375 the overarching aim was to assess the causes and impacts of slow slip earthquakes as well as to investigate large submarine slides associated with gashydrates offshore North Island, New Zealand. Sediments have been drilled and sampled down to the Cretaceous including intercalated tephra layers from the Miocene to Holocene. The drill sites are located in the Pacific, ~250 km downwind of the Taupo volcanic Zone (TVZ), one of largest and most frequently active silicic centers on earth, and also close to the Coromandel volcanic zone (CVZ) a sparsely investigated Neogene volcanic arc. The tephra inventories of these intermediate distant sites provide the missing link between the proximal (<~100 km) terrestrial and very distal (~1000 km) ODP sites to establish a nearly complete eruptive history from the early Miocene to recent for New Zealand´s explosive volcanism.

This project focuses therefore on the volcanic products from highly explosive eruptions from New Zealand during the Neogene and Quaternary. Tephra deposits from Exp. 372&375 complemented by tephras found on land and in older and more distal ODP drill cores provide the unique opportunity to investigate and compare the history of highly explosive volcanic activity of both arc systems (CVZ and TVZ), and their signals in marine sediments over a time span of about at least 12 Myrs.

Geochemical, petrological and volcanological approaches for tephra and sediment characterization will be used to quantitatively and qualitatively decrypt their provenance and the eruption succession even for smaller eruptions potentially available as cryptotephras. Especially the crucial gap in trace elements, in both, terrestrial and former marine samples, will be filled. Additionally, we will perform absolute age dating to improve and confirm the existing age models. Robust age models are needed to study the temporal and spatial changes in eruption processes, magnitudes and frequencies of large volcanic eruptions from both, the TVZ and CVZ.

Finally the herewith-established compositional data and eruptive time series will serve as base to address questions regarding recurrence rates and cyclicities in both systems, covering the first time also a Neogene eruption time series. It will also facilitate the temporal and quantitative characterization of the sediment composition at the slope and at the incoming plate in relation to the volcaniclastic input and answer the question how this may influence the mechanical, frictional, and hydrogeological properties of the sediments. Additionally the data provide a tool to backtrack displaced sediment blocks of the Hikurangi margin on the base of sediment geochemistry and tephra layers.

IODP

Indian Summer Monsoon variability across Termination I based on the stable hydrogen isotope composition (?D) of terrestrial plant leaf wax n-alkanes from IODP Site U1446 (Bay of Bengal)

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Understanding teleconnections and feedback mechanisms in the global climate system in the past is of key importance for reliably assessing its behaviour under future global warming scenarios and how this may affect modern societies and economies. This is particularly true for the Asian monsoon system, whose variability influences the daily life of billions of people and thus also global economy. Existing knowledge about the long-term evolution of the Asian monsoon system is mainly based on proxy records from speleothems and marine sediments (e.g. Bolton et al., 2013; Clemens & Prell, 2003; Cheng et al., 2016; Deplazes et al., 2014; Kathayat et al., 2016; Mohtadi et al., 2010; Thomas et al., 2014; Wang et al., 1999; Wang et al., 2001). Among these, particularly the Chinese speleothem records have provided evidence for a dominant influence of Northern Hemisphere summer insolation, i.e. changes in the Earth?s orbital parameters, on long-term Asian monsoon variability (e.g. Cheng et al., 2016). On shorter time scales, there is furthermore evidence for centennial- to millennial-scale reductions in monsoon precipitation, so-called Weak Monsoon Intervals (WMIs), which occurred synchronously to cold intervals in the North Atlantic realm, e.g. during Heinrich Events (e.g. Cheng et al., 2016; Deplazes et al., 2014; Kathayat et al., 2016; Wang et al., 2001). This points towards a close hemisphere-scale climatic teleconnection between the North Atlantic and the Asian monsoon system, but the exact mechanisms and thus the drivers that control short-term monsoon variability in Asia have until now remained elusive. In this context, the improved understanding of short-term variability of the Indian Summer Monsoon (ISM) is mainly hampered by the still limited number of high-resolution proxy records from the core zone of the ISM that provide information about both (1) changes in terrestrial monsoon precipitation and (2) changes in oceanographic conditions that possibly control short-term ISM variability. So far, the only marine proxy record from the region, i.e. the Bay of Bengal, which provides information about monsoon-driven changes in precipitation and vegetation on the Indian subcontinent, covers just the last ~18 kyr (Contreras-Rosales et al., 2014). It also does not provide parallel information about changes in ocean conditions, thus leaving large uncertainties regarding short-term ISM changes, their terrestrial impact and the possible oceanographic control mechanisms, particularly for the period prior to Termination I.

To overcome the uncertainties regarding past short-term ISM variability and to investigate the possible relation between changes in monsoon precipitation and oceanographic conditions in the Indian Ocean, the Weak Monsoons Project has been initiated in 2017. Sediments obtained from the northwestern Bay of Bengal during IODP Expedition 353 at Site U1446 (Clemens et al., 2016) are analysed for the stable hydrogen (δD) and carbon ($\delta^{13}C$) isotope composition of terrestrial plant leaf wax *n*-alkanes in order to reconstruct ISM variability and associated vegetation changes on the Indian subcontinent during the last ~75 kyr. These data will be complemented by µXRF major element, pollen and alkenone-based UK'37 sea surface temperature records from the same sediments, allowing a comprehensive view on past ISM variability and its trigger mechanisms and particularly on centennial- to millennial-scale WMIs. As IODP Site U1446 is located at a relatively near-shore position within the reach of the Ganges?Brahmaputra-Meghna river system, it is characterized by high sedimentation rates as well as high input of terrestrial organic matter via river runoff, making it an ideal location for high-resolution analyses of the δD and $\delta^{13}C$ composition of terrestrial leaf wax n-alkanes in order to reconstruct past precipitation and vegetation changes on the Indian subcontinent at high temporal resolution. Here we present preliminary concentration and δD records of the long-chain terrestrial n-alkanes *n*-C_{27} to *n*-C_{33} for the time interval between ~10 and ~25 ka BP, which is characterized by major changes in the ISM system. By comparing these data to other regional proxy records, we aim at characterizing ISM changes across Termination I in more detail.

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ICDP

3D-VSP experiment at the Alpine Fault DFDP-2 drill site in Whataroa, New Zealand

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The plate-bounding Alpine Fault in New Zealand is an 850 km long transpressive continental fault zone that is late in its earthquake cycle. The Deep Fault Drilling Project (DFDP) aims to deliver insight into the geological structure of this fault zone and its evolution by drilling and sampling the Alpine Fault at depth (Townend et al., 2009). Results from the drilling reveal an active hydrothermal circulation system in the hanging wall with a wider damage zone around the main Alpine Fault core (Townend et al., 2017), however, the detailed structures of the fault system remain unknown.

Previously analysed 2D reflection seismic data image the main Alpine Fault reflector at a depth of 1.5-2.2 km with a dip of approximately 50° to the southeast below the DFDP-2 borehole (Lay et al., 2016). Additionally, there are indications of a more complex 3D fault structure with several fault branches which have not yet been clearly imaged in detail.

For that reason we acquired a 3D-VSP seismic data set at the DFDP-2 drill site in January 2016 (Townend et al., 2016). A zero-offset VSP and a walk-away VSP survey were conducted using a Vibroseis source. Within the borehole, a permanently installed "Distributed Acoustic Fibre Optic Cable" (down to 893 m) and a 3C Sercel slimwave tool (down to 400 m) were used to record the seismic wavefield. A first analysis of both borehole data sets shows a good correlation of both recording systems (Constantinou et al., 2016). Furthermore, the velocity features coincide with results obtained previously from borehole logging.

In addition, various receiver systems recorded the seismic wavefield at the surface: (i) an array of 160 three-component receivers, moved successively along the valley during the survey, (ii) two lines of 400 Aries vertical-component receivers parallel to source lines, (iii) five Reftek stations and (iv) a small-aperture far-offset vertical-component geophone array.

In the following, we will discuss the data set for the three-component receiver array in more detail. First, the receivers were widely distributed within the Whataroa valley during the multi-offset source lines. This data set is used to verify and improve the existing velocity model derived from a previously acquired 2D reflection line (Lay et al., 2016).

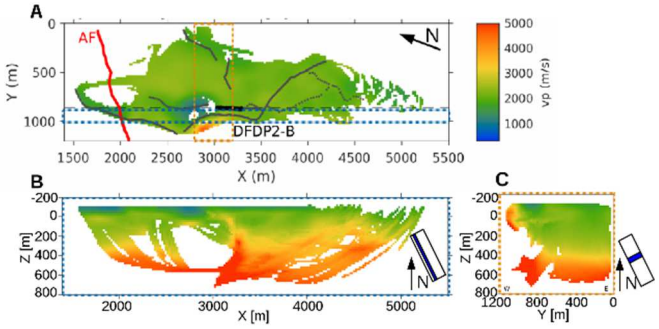

Fig. 1: The tomographic P-wave velocity model using all subsets of the data set is shown for parts with sufficient ray coverage. The borehole trajectory of the DFDP-2B borehole (black) and the assumed Alpine Fault surface trace (red) are marked. A) x-y plane at a depth of z=-40 m. Blocks shown in B (blue) and C (orange) are marked. Source locations are marked by grey stars. B) x-z-slice calculated by a mean within the interval y=800-1000 m. C) y-z-slice calculated by a mean within the interval x=2800-3200 m.

Second, a source loop with 71 different source locations was acquired with a total of 3502 sweeps. The 160 receivers were set up as an array with a spacing of 10 m perpendicular and 20 m parallel to the main strike of the Alpine Fault. The whole array was moved successively along the valley twelve times to record reflections from the main Alpine Fault zone over a broad depth range. Altogether, 1916 receiver locations were recorded for the 71 source locations. Thus, the detailed 3C array densely covers an area within Whataroa valley of approximately 1800 m inline along the river (i.e., perpendicular to the fault strike) and 600 m crossline perpendicular to the river (i.e., parallel to the fault strike).

A detailed 3D velocity model was derived by first arrival tomographic inversion (see Figure 1). Subsets of the whole data set were analysed separately to estimate the corresponding ray coverage and the reliability of the observed features in the obtained velocity model. After testing various inversion parameters and starting models, the final detailed near surface velocity model reveals the significance of the old glacial valley structures. The glacial sedimentary infill has lower P-wave velocities (~2300 m/s) in comparison to the basement (~4200 m/s). Interestingly, the high P-wave velocities associated with the basement are found at very shallow depths in the West indicating a steep valley flank.

These shallow high velocities correlate with the southwestern valley flanks (circa at y=1100 m). Particularly, cross-sections of the valley (e.g. Figure 1C) indicate 3D structures that were not detectable with the previous 2D data set. Additionally, analyses of the first-arrivals recorded in the borehole show systematically slower P-wave velocities in comparison to arrivals at surface recorders. Taking into account the different raypaths, this can be explained by anisotropy which would be in agreement with the geologically identified foliated schists and mylonites dipping ~50° to the Southeast (Toy et al., 2017).

Within the dense 3D seismic data set, single reflection events are identified on both inline and crossline profiles so that the spatial origin of reflections can easily be identified. Seismic images obtained by prestack depth migration show reflectors that correlate with the steeply dipping valley flanks as well as with previous studies and recent findings from the drilling.

Hence, the 3D seismic data improves both the P-wave velocity model and the seismic images. The glacial valley structures and the respective reflections can correctly be located which will help to obtain an image of the Alpine Fault zone at depth. Thus, the results provide a basis for a seismic site characterization at the DFDP-2 drill site, which will be crucial to understand the structural and geological architecture of the Alpine Fault zone in this area.

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ICDP

Tephrostratigraphy and tephrochronology of a 430 ka sediment record from the Fucino Basin, central Italy

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The Fucino Basin is the largest and probably the only Central Apennine basin hosting a continuous and thick lacustrine sediment succession documenting the environmental history from the Early Pleistocene to the 19th century. The Fucino basin is downwind of the peri-Tyrrhenian volcanic centres (< 150 km) which makes it the best candidate available in the central Mediterranean to construct a long and continuous tephrochronological record. Tephra layers recorded can be independently dated with 40Ar/39Ar geochronology and directly anchored to a comprehensive time series of paleoenvironmental proxies hosted by the lacustrine sediments. The Fucino lacustrine archive also provides the opportunity to extend the existing network of long terrestrial Mediterranean records (e.g. Dead Sea, Lake Van, Lake Ohrid, and Tenaghi Philippon) to the west, a currently vacant area. Transferring chronological and stratigraphic information on paleomagnetic excursions and long- and short-term climate variability to North Atlantic climate records sets the framework for a better understanding of the spatio-temporal variability, the magnitude, and the different expressions of Quaternary orbital and millennial-scale paleoclimatic changes.

In June 2015, a ~82 m-long sediment succession (F1-F3) was recovered from the eastern-central area of the Fucino Basin. The lithology of the sediments is dominated by fine-grained lacustrine sediments composed of grey calcareous marl with variable proportions of clay and organic matter (Giaccio et al., 2015). Twenty-one tephra layers constrain the chronology of the core continuously back to 190 ka. These tephra layers originate from different Italian volcanic complexes, such as Campi Flegrei, Etna, Colli Albani, Ischia, Vico, Sabatini, and undefined volcanic sources in the Neapolitan area and Latium region. They comprise key Mediterranean marker tephra layers, such as the Neapolitan Yellow Tuff, Y-7, C-22, X-5, and X-6. Trace element and isotope analysis helped to reveal the volcanic origin of so far unknown tephra layers, of which some were additionally 40Ar/39Ar dated (Giaccio et al., 2017). The tephrochronological information is the basis for the establishment of an independent chronology of the F1-F3 core and to correlate geochemical and bio-geochemical data from F1-F3 to climate variability.

Based on these promising results, an ICDP-workshop proposal was submitted in 2017 in order to establish an ICDP deep drilling campaign. The ICDP initiative aimed at recovering the entire lacustrine succession of the Fucino basin and to establish an independent radioisotopically-anchored chronology for the last ~1.3 Ma, which can be propagated from the regional to the global scale. The proposal was rejected, but in order to answer the

improvements requested and to provide further fundamental results to demonstrate the global significance of the record, respective additional studies were intended. An international consortium of several scientists and institutions, including IGAG-CNR (Italy), IGG-CNR (Italy), INGV (Italy), LIAG (Germany), and the universities of Pisa (Italy), Rome (Italy), Cologne (Germany), Geneva (Switzerland), and the BGS (UK) provided funds for a new coring campaign and borehole logging. At the new F4-F5 site, which is located ~2 km west of the F1-F3 site and characterized by a lower sedimentation rate, two ~86 m long cores were recovered in summer 2017. Borehole logging was carried out at the F4 site down to ~80 m.

First core analyses comprised multi-sensor core logging (MSCL, GEOTEK Co.), line scan imaging, XRF scanning (ITRAX, COX Ltd), and whole-core paleomagnetic analysis (760 SRM, 2-G Enterprises). Based on these data sets and on optical information after core opening, the individual, overlapping 1.5 m long sediment sequences have been correlated to a core composite. Subsampling of discrete sediment samples and tephra horizons for detailed paleomagnetic, geochemical, sedimentological, geomicrobiological, and tephrostratigraphical studies recently started. Throughout the core composite, important marker tephra horizons were recognized and enabled dating the base of the record back to the MIS 12-MIS 11 transition (~430 ka). Visible core inspection and XRF-downcore data suggest the presence of more than 130 tephra and cryptotephra horizons, which detailed study, has a huge potential to reveal new insights into the volcanic history of the peri-Tyrrhenian volcanism for the poorly explored 200–400 ka time interval. The high number of tephra horizons forms the backbone to build an independent radioisotopically-anchored chronology that can be transferred via tephrostratigraphic and/or climatostratigraphic correlations to other records from the Mediterranean and North Atlantic realms.

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IODP

Interhemispheric Gradient of Nd isotopes in the Deep Atlantic Ocean since 800 ka

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According to Pena and Goldstein (2014) the fundamental change in glacial-interglacial periodicity at the mid-Pleistocene transition (MPT) at around 900 ka was marked by a major disruption of the ocean thermohaline circulation (THC) system recorded in Nd isotopes. It was also inferred that the transition into the post-MPT 100-thousand-year world was characterized by sustained weak glacial THC. But presently, only two sites with Nd isotope reconstructions resolve the systematic nature of Pacific versus Atlantic water mass competition over numerous climate cycles and on millennial time scales for the past 800 ka (ODP929: Howe & Piotrowski 2017; and ODP 1063: this study). We use these two records for assessing the latitudinal gradient of deep water Nd isotopes between North source and southern bottom waters. In case either North Atlantic overturning or AABW production dominates the entire deep flow, the Nd isotope gradient between the northern (ODP 1063) and southern (ODP 929) sites is expected to disappear. We observe weak glacial overturning in the deep Northwest Atlantic expressed by a vanishing Nd-isotope gradient solely at the end of the major glaciations. In contrast, during warm climates and strong overturning the Nd-isotope gradient persisted and varied between a value of 2 to 4 εNd units. This confirms the suggestion that glacial overturning was disrupted exclusively during major northern hemisphere ice sheet instability (Böhm et al. 2015) and thus was an exceptional circulation state during the past 800 ka.

Overall, the changes of εNd values of both records were strongly coupled at a 100-thousand-year cyclicity, with the amplitudes of the northern site being roughly twice as large as the equatorial site. Consequently, the sensitivity of εNd along the flow path computed as the change of εNd per degree latitude decreases from interglacial to glacial circulation. Interestingly, the pre-MPT latitudinal gradient of Nd isotopes as recorded in ODP 1063 and South Atlantic Site ODP 1090 (Pena and Goldstein 2014) yield a higher sensitivity. Nevertheless, we presently lack sufficiently resolved southern hemisphere records tracing both the interface between northern and southern water masses as well as the southern source end-member values through the past one million years. One record, however, presented by Dausmann et al. (2017) nicely resolves a south Atlantic glacial – interglacial water mass competition using εNd, but the end-member values as well as the millennial variability is not resolved. This inhibits conclusive interpretations on the absolute Nd sensitivity as water mass tracer before and after the MPT. Therefore, we propose to generate a one million year benchmark Nd isotope record in the deep Cape Basin.

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IODP

Atlantic-wide deep circulation patterns during MIS 11

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Over the glacial-interglacial cycles of the past one million years, Marine Isotope Stage (MIS) 11 stands out in many terms. Firstly, it is considered as a possible analogue to the Holocene and the upcoming future, as the orbital configurations of both time periods are pretty similar (Loutre and Berger, 2003). Extreme warmth in the Arctic and in Northern Scandinavia has led to the term "super-interglacial" for MIS 11 (Lauritzen and Lundberg, 2004; Melles et al., 2012). A relatively high sea-level with +6-13m (Dutton et al., 2015) and the very long duration of nearly 30 kyrs fit into the overall picture of a special interglacial. While traditional proxies like $\delta^{13}C$ indicate a strong Atlantic Meridional Overturning Circulation (AMOC) during MIS 11 (e.g. Dickson et al., 2009), concern arose regarding the deep water formation in the Nordic Seas because of the freshwater input coming from a melting Greenlandic Ice Sheet (Kandiano et al., 2016).

To reconstruct the routing of the deep water masses and the dynamics of the AMOC, we use neodymium isotopes of the authigenic fractions of deep sea sediment. They act as a recorder of the signature of bottom water masses and track the provenance of those. In order to get not only a temporarily but also spatially highly resolved reconstruction, sediment cores from all over the Atlantic Ocean are selected to be processed in this project.

Here, we present the first results for sediment cores situated in the Northern Hemisphere. Records have been completed for sediment cores ODP 980 at the Feni Drift, and IODP U1304 at the southern limit of the Gardar Drift and therefore located close to the overflow waters. Along the flow path of deep water we have further completed records from the Bermuda Rise, ODP 1063, and the Romanche Fracture Zone, ODP 664. Together with the previously published dataset of core ODP 929 at the Ceara Rise, the records show a large spatio-temporal variability across Termination V.

Overall, the pattern resemble the respective Holocene records and in cases exceed the isotopic gradients across Termination V.

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IODP

Crystallization conditions of fore-arc basalts from the Izu-Bonin-Mariana island arc: experimental constraints

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The process of subduction is considered as one of the major manifestations of a dynamic Earth. However, little is known about how subduction starts and proceeds. According to one of the first conceptual model of Stern and Bloomer (1992), in the course of subduction initiation, the old and relatively dense oceanic lithosphere begins to sink into the asthenosphere. Lithosphere in the upper plate adjacent to the sinking lithosphere rapidly extends into the gap left as the dense lithosphere sinks. In this setting, mantle flows into the nascent mantle wedge and interacts with a small and variable contribution of fluids from the sinking plate. Melting induced by the fluid augments that resulting from decompression, leading to a higher degree of melting than at mid-ocean ridges. These MORB-like lavas with arc-signatures originating in this setting have been recently termed as forearc basalts (FABs, Reagan et al. 2010). Combination of rapid decompression melting with fluid enhanced lowering of the solidus leads to more extensive melting of the shallow asthenospheric wedge, creating refractory Mg-rich and Si-rich lavas such as boninites and high-Mg andesites and leaving an extremly refractory harzburgitic residue (Shervais, 2001). In the Stern-Bloomer model, the presence of boninites at the top of a FAB lava sequence is a major indicator of a subduction-initiation setting (Pearce, 2014). The knowledge on the main changes in magma origin and magma evolution conditions at the transition from FAB to boninite is crucial to understand the general process of subduction initiation, the role of mantle reorganization and specifics of mantle melting regimes.

In 2014 IODP Expedition 352 succesfully recovered 1.22 km of igneous basement of FABs and boninites at four drilling sites (Expedition 352 Scientists, 2015). The expected sequence of FABs underlain by boninites was however not encountered. In contrast, dikes at the base of FABs (Sites U1440 and U1441) and boninite (Sites U1439 and U1442) sections provided rather an indication for independent conduit systems for FABs and boninite magmas which were offset more horizontally than vertically (Expedition 352 Scientists, 2015). Here we present the results of petrological and experimental investigations of the recovered fore-arc basalts.

Fore arc basalts are typically aphyric to sparsely phyric, plagioclase-pyroxene-phyric basalts and dolerites. Olivine phenocrysts are not present in lavas, only sporadically crystalls have been met in less differentiated glassy samples with more than 8wt% MgO. Its composition ranges from 81 to 76 mol% Fo. Anorthite contents of plagioclase and Mg# number of clinopyroxene pheno- and subphenocrysts cores are ranging from 86 to 60 (mol%) and from 0.86 to 0.53 respectively. Across the Hole U 1440 An in Plag and Mg# in Cpx behaves s-shaped in which the units 2, 3, 7,8 and 14 show higher An and #Mg values than the remaining units of 3, 6 and 13. Bigger units like 7,8 and 14 exhibit a higher variability of these values between different sample cores.

Our whole rock compositions of FAB lavas erupted at Sites U1440 and U1441 range between 5 and 8 wt% MgO. FAB glass compositions are generally in the range of whole rock compositions. However, they have slightly higher FeO and systematically lower Al_2O_3, Na_2O and K_2O contents. The differentiation trends obtained from whole rock major element compositions (from basalt to andesite) indicate that the analyzed samples can only be derived from slightly different parental magma compositions. For example, the most primitive FAB magmas from UNIT 3 are too poor in TiO_2 to be parental for the less evolved magmas from other groups. Results of our phase equilibria simulations conducted for several representative starting compositions indicate that a slight variability in primitive FAB magmas is required to let them follow natural liquid lines of descent and match the natural glass compositions. It should be noted that all calculations have been conducted in the range of low melt H_2O contents (0.1 to 0.8 wt%). This low water content was confirmed by FTIR analyses of the dissolved H_2O in naturally quenched glasses. An interesting feature of the FABs is the very narrow compositional range of glass compositions sampled at the top (UNIT 2), the middle (UNITs 7 and 8) and bottom (UNIT 14) of the core in site U1440, indicative of similar magma storage conditions over time. However, this homogeneity of magma storage conditions is sometimes interupted as demonstrated by the eruption of magmas representative of Units 6 (andesites) and 13 (H_2O -rich). The most evolved glasses from UNIT 6 and intermediate Al2O3-enriched glasses from UNIT 13 cannot be produced by fractional crystallization of primitive melts from the UNITs 2, 7, 8 and 14 and require even more contrasting parental melt compositions. The Unit 6 andesite also requires more than 85% fractionation of magnetite-bearing phase assemblage and has trace element pattern somewhat different from other FABs. The basaltic glass from UNIT 13 strongly differs from other FABs showing anomalously high H_2O contents (~2 wt%), higher Al_2O_3 and lower FeO indicative of crystallization under hydrous conditions (Danyushevsky, 2001).

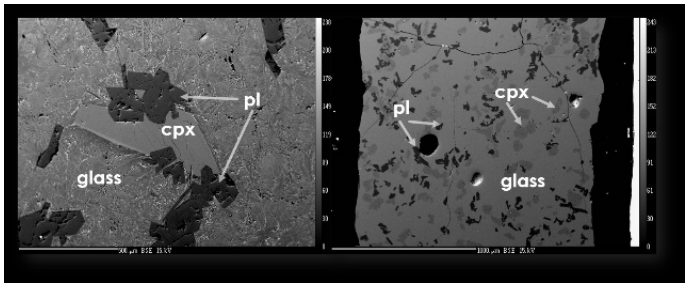

Figure 1: Comparison of natural and experimental phase assemblage with clinopyroxenes and plagioclases. FAB experiments with 100 MPa 1150 °C, FMQ show the crystallisation of cpx and pl like natural rocks.

The good match of modelled and natural liquid lines of decent observed for UNITs 2, 7, 8 and 14 demonstrate that modelled intensive parameters can be considered as pre-eruptive conditions: low H_2O (0.1-0.8 wt%), and low-pressure (most likely below 100-200 MPa). The low pressure conditions (~100 MPa) have been confirmed by the modelling the conditions of multiple saturation in less differentiated glasses saturated with olivine, plagioclase and clinopyroxene (using the approach from Almeev et al., 2008). It should be noted, however, that application of cpx-melt and plag-melt geothermobarometers (Putirka, 2008) revealed systematically higher pressures and also a larger pressure range of partial crystallization (200-600 MPa). However, such higher pressures are not realistic. At high pressure, FAB melts with their high CaO/Al_2O_3~0.9 (in MORBs: CaO/Al_2O_3<0.85) should exhibit clinopyroxene alone crystallization on their liquidus. This contradicts with natural observation of the presence of both clinopyroxene and plagioclase (+ olivine in some primitive samples) phenocrysts in lavas.

Crystallization experiments in FABs were designed to address the following major goals: (i) Determination of liquidus phases: in our calculations we were not able to produce Olivine-free Plag-Cpx cotectic crystallization. The modeling predicts that olivine crystallization is expected over a long crystallization interval, even after 30-40% crystallization with melts having 6 to 8 wt% MgO contents, which is predominant in natural FABs. Howver, olivine is rare in the natural samples and natural FABs with similar MgO concentrations are olivine-free lavas. Therefore one important question is to understand which parameters control the near-liquidus phase assemblage Plag-Cpx in primitive FAB; (ii) Determination of depth of magma storage: the experimental constraints are helpful to resolve the discrepancy in pressure estimates obtained from phase equilibria simulations of FAB crystallization (model COMAGMAT) and from results of mineral-melt geothermobarometry (using Putirka, 2008 formulations); (iii) Determine the role of fractional crystallization in genesis of the FAB magmas.

Two synthetic analogues of the FAB glasses 352-U1440B-12R-2W-67cm and 352-U1440B-24R-1W-13cm (with 8.5 and 7.5 wt% MgO

respectively) have been used to determine experimentally equilibrium phase assemblages at 100 MPa under nominally dry conditions in internally heated pressure vessels under intrinsic oxygen fugacity conditions. Two capsule configurations were used to model (a) anhydrous (<0.1 wt% H_2O) and reduced (FMQ-1) conditions using Pt-lined graphite capsules and (b) low H_2O (~0.6 wt% H_2O) and oxydized (FMQ) conditions in Fe-presaturated $Au_{20}Pd_{80}$ capsules. Plagioclase and clinopyroxene were present in products at 1175, 1150 and 1125°C under both anhydrous and low H_2O conditions. This perfectly fits to the phenocrysts assemblage observed in natural FABs. The experimental liquid lines of decent are in a good agreement with those defined by natural glass compositions. This allows us to conclude that thermodynamic conditions utilized in our experiments (100 MPa; 1175-1125°C; FMQ-1<logfO_2<FMQ+0.5) can be potentially considered as conditions of partial crystallization of the Units 7-8-14 and 13 FABs (Figure 1).

However natural mineral compositions are not fully reproduced (experimental plagioclase is too calcic and clinopyroxenes are too magnesian). In addition, clinopyroxene alone was observed in experiments at high temperature (1200°C) and not the cotectic assemblage Cpx+Plag, which is always observed in the natural Plag+Cpx bearing FAB lavas. This inconsistency can be explained either by (1) too high experimental pressure which favours crystallization of the clinopyroxene, or (2) by slight differences between our synthetic starting compositions and the natural FAB glasses. However, strong deviations of the starting compositions from the natural glasses are not observed and the most important changing parameter is the CaO/Al_2O_3 ratio (0.92 in the starting materials and 0.9 in natural counterpart).

To check and constrain the effect of pressure, additional set of experiments at 50 and 200 MPa have been conducted for both dry an low H_2O conditions. At both pressures, only clinopyroxene was observed at 1200°C. To compare all varieties of pressure, exceptional experiments have been conducted under 1 atm and 1190 °C. Missing crystallization of olivine could have been observed under conditions of FMQ.

However due to the submarine character of FAB magma eruptions, there is no geological evidence to assume partial pressure of crystallization below 50 MPa. Therefore the problem of early Cpx crystallization can be attributed to the slight discrepancy between synthetic starting material and natural glass compostion. This does not affect the general results of our experimental simulations (e.g., equilibrium compositions between melts and minerals). However, our observations show that very small variations of CaO/Al_2O_3 ratio influence significantly the phase equilibria and possible the trace element distributions in residual melts.

In summary, according to our experimental investigations and results of the modelling we suggest that crystallization of typical FAB magmas should have proceeded in shallow level systems at ~100 MPa. The H_2O content of melts with 6-8 wt% MgO is low (<0.8%). Our experimental data show that residual liquids produced under FMQ-1 and FMQ conditions are nearly identical on Harker diagrams, indicating that variations of redox conditions in the range FMQ-1 - FMQ + 0.5 (corresponding to reducing conditions) are not expected to influence significantly liquid lines of descent. The similar liquid lines of descent are mostly explained by the absence of magnetite in the crystallizing phase assemblage, which is only expected at more reducing conditions. An additional constraint on the prevailing oxygen fugacity could be obtained by comparing the Fe^{2+}/Fe^{3+} ratios in the natural and experimental glasses.

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IODP

New proposal: Marine dating of the impact crater beneath Hiawatha Glacier in Greenland

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A large, relatively young impact crater of considerable size beneath the Hiawatha Glacier in NW Greenland has recently been reported from radiostratigraphy observations [1]. Geophysical, geological and geochemical evidence suggest that the impact of a >1 km fractionated iron meteorite (as derived from the crater size and elevated concentrations of Ni, Co, Cr, Au and Platinum Group Elements (PGE) in glaciofluvial sediment) caused the newly discovered >30 km diameter bedrock depression below ~1 km of ice [1].

While the exact age of this impact crater is presently unknown the radiostratigraphic data of the ice above the crater indicates the Holocene ice layer as continuous and conformable. In contrast, all older parts appear rich in debris and/or heavily disturbed. The authors reporting this crater for the first time thus struggle constraining the time range of the impact from radiostratigraphic observations alone [1]. Due to the undisturbed Holocene ice sheet sequence the youngest possible impact date would be the last Deglacial. Although the could be as old as 3 Ma, the high abundance of entrained debris in the highly deformed and disturbed lower section may point towards a relatively young impact age [1].

The exact age, of course, would be of high interest, but this would require a new quite expensive ice-drilling project. Here we propose an alternative approach for impact age reconstruction, from analysis of nearby ODP sediment cores.

Impactors of such sizes leave characteristic geochemical and mineralogical imprints in the wider environment like anomalies in e.g. Ga, Ge, Co, Cr, Cu, Fe, Ni, Pt, Os, Ir, Ru, Pd depending on impactor and target rock composition (e.g. [5]) as well as potentially direct evidence from shocked quartz or microtektites (e.g. [2-4]). In the case of a > 1km iron meteorite such anomalies are expected to be detectable within the wider surroundings of the impact area (as e.g. found from the similarly sized Mjølnir crater [6, 7].

In a feasibility study we showed that iridium and other PGE released from a ~1 km iron meteorite should be detectable in adjacent marine sediment cores for a wide range of reasonable impact scenarios and parameters. The crater is located at the northwestern corner of Greenland close to the Baffin Bay and the Lincoln Sea of the Arctic Ocean. It can be assumed that material from the vaporized meteorite and the Precambrian target rocks have been deposited in the sediments beneath these seas.

In order to identify this impact in the marine realm we intend to make use of two sites in relative neighbourhood of the newly discovered crater: Leg 105 ODP Site 645 and Leg 151 ODP Site 910, which can be expected to have been significantly affected by the geochemical and cosmochemical characteristics of such a massive event. Although both cores suffer from a relatively poor recovery on the whole core length, both cores hold continous upper core [8, 9]. From both sites stable isotope records are available allowing for a rough identification of the MIS2-MIS1 transition. Both cores will be examined for traces of the impact like PGE anomalies and microtektites, spherules and/or shocked quartz. After evidence for an impact has been identified the relevant core sections will be dated by the combination of high resolution ^{14}C-dating and the alignment of major element abundances to Greenland ice-cores $\delta^{18}O$ [10]. Radiocarbon dating can be performed on planktic foraminifera for dates < 45 ka, which do not need to be very abundant in the sediments due to the recent advances of AMS regarding the sample input systems [11,12]. By this approach an age error of the impact date is expected to be in the centennial age range. Comparison of the relative abundances of the platinum group elements, the ages of shocked zircons, and the composition of microtektites with those from Greenland glaciofluvial sediments [1] will allow us to link impact debris in the ODP cores with the Greenland impact crater.

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ICDP

Early hominin dietary adaptation in diverse savanna ecosystems

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Clumped and stable isotope data of paleosol carbonate and fossil tooth enamel inform about the Pleistocene paleoenvironments early hominins thrived in. Data on woodland- vs. grassland dominated ecosystems, soil temperatures, aridity, and the diet of Homo rudolfensis and Paranthropus boisei ca. 2.4 Ma ago show that both hominin taxa were adapted to C3 resources in wooded savanna environments in relatively cool and wet climates in the southern part of the East African Rift (Malawi Rift). In contrast, time-equivalent Paranthropus living in open and drier settings in the northern East African Rift relied on C4 plants, a trend that became enhanced after 2 Ma, while southern African Paranthropus persistently relied mainly on C3 resources. In its early evolutionary history, Homo already showed a high versatility, suggesting that Pleistocene Paranthropus as well as Homo were already dietary generalists.

ICDP

A 150,000-Year Vegetation and Climate History: The New Dead Sea Pollen Record

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The Dead Sea is a salt lake in the Eastern Mediterranean that occupies the lowest depression on Earth. It witnessed a dynamic history with strong lake level variations and salinity changes. In addition, the Dead Sea region is a key site for investigating the history of mankind because it accommodates important archaeological remains of modern humans and Neanderthals. Yet, our knowledge about the paleoenvironment and particularly the vegetation history of the Dead Sea region was still fragmentary.

Here, we present new pollen data inferred from sediments of the Dead Sea. The sediments were recovered from the center of the lake in the frame of an ICDP campaign. They represent the longest continuous sediment record of the southern Levant. We investigated more than 250 m of the sediment core spanning the last interglacial-glacial cycle. The palynological results indicate the occurrence of Irano-Turanian steppe, Saharo-Arabian desert vegetation, and Mediterranean woodland. The abundance of these vegetation types changed through time in response to the climate conditions. The last interglacial was initiated by a warm and dry phase marking a pronounced environmental change. It was followed by a spread of drought-adapted trees and shrubs such as olive trees suggesting seasonally more available moisture. During the last glacial, seasonality was less extreme. Artemisia steppe gradually increased until MIS 2, which was the coldest phase of the investigated timeframe.

The study gains new insights into environmental responses of the Dead Sea region to climate variations in the past. It contributes towards our understanding of paleoenvironmental conditions in the southern Levant, which functioned as a principal corridor for human migration processes.

IODP

New Insights into Lower Crustal Accretion at Fast-Spreading Mid-Ocean Ridges – Petrological and Microstructural Results from the ICDP Oman Drilling Project

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The Samail Ophiolite in the Sultanate of Oman and the United Arab Emirates is regarded as the largest and best-exposed analogue of fast-spreading oceanic crust on land. The ICDP Oman Drilling Project (OmanDP) obtained nine drill cores, each with a length of either 300 or 400 m, sampling the basal thrust, active mantle alteration, the crust/mantle boundary and the lower, mid, and upper gabbros (GT) up to the dyke/gabbro transition. All cores have been described during two core description phases on board of the Japanese IODP drilling vessel CHIKYU, establishing a close link between IODP and the OmanDP.

Since layering is a common feature in lower crustal gabbros from fast-spreading mid-ocean ridges, understanding its formation will be crucial for a proper understanding of lower crustal accretion in general. Therefore, the two main goals of this project are (1) to investigate modal and grain size layering within the lower crustal gabbros in detail and (2) to constrain details of the accretion of the lower oceanic crust, with reference to the two most popular end-member models, the *sheeted sill model* [1] and the *gabbro glacier model* [2]. The OmanDP sites GT1 and GT2 provide detailed insights into series of both foliated and layered gabbros. These sites are located in the Wadi Gideah (Wadi Tayin Massif, Samail ophiolite) and can be placed within a reference profile from the Moho to the upper crust, also from Wadi Gideah [3]. Here we investigate the samples' petrology, geochemistry and microstructures.

To study layer-forming processes, samples of different lithologies and of coherent layer transitions were chosen. Analyses are currently being performed at Hannover (electron probe microanalysis), Kiel (laser ablation inductively-coupled plasma mass spectrometry and bulk rock major and trace elment geochemistry) and Montpellier (France; EBSD: electron back-scattered diffraction).

Alongside the typical primary lithologies of gabbro and olivine gabbro, the GT1 and GT2 drill cores contain a few coherent, mm- to cm-thick troctolitic and ultramafic (dunitic, wehrlitic) layers that were not observed during previous, convenitional sampling of the Wadi Gideah transect [3]. This demonstrates the benefits of scientific drilling versus conventional sampling, especially in case of the OmanDP where recovery was typically close to 100%.

Both cores show clear modal layering on mm- to m-scales. Grain size layering is observed as well, but is not as common as modal layering. Clinopyroxene is the most common mafic phase and shows clearly increasing grain sizes with increasing modal abundances. A similar – but weaker – correlation is also observed for plagioclase. Following Stoke's law, this correlation indicates that gravitational sorting plays a key role in the formation of modal layering. First mineral analyses reveal Mg# (Mg / (Mg+Fe)×100; molar basis) between 78 and 86 in clinopyroxene and Ca# (Ca / (Ca+Na)×100; molar basis) in plagioclase varying between 68 and 88. Most olivines are heavily altered with rare relict pristine occurrences showing Mg# between 74 and 80. These results are in good agreement with analyses from the reference profile, however, due to the much higher spatial resolution of the drilled samples, clear trends on a scale of tens of meters can be observed: both Mg# and Ca# have their minimum at a crustal height of 1050 m above the Moho and increase progressively up and down section, respectively. This variation correlates with a significant decrease in the BA index of plagioclase, which quantifies the pole figure symmetry of each crystallographic axis and distinguishes between point, girdle, and random distribution, representing a

more foliated symmetry in the region of more fractionated mineral compositions. A correlation between mineral composition and crystal preferred orientation obtained with EBSD along the cores indicates that the crust was not crystallized within a single melt batch according to the *gabbro glacier model*, but could be explained by in-situ crystallization in a system of multiple sills.

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ICDP

Permeability's role around magma bodies: a way for gradually deforming or suddenly erupting

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Many of Iceland's electricity-producing geothermal fields are located within or near explosion craters produced by steam-driven eruptions. The Krafla geothermal area is a prime example of such a valuable infrastructure resource with an uncertain hazard future. The *Vití* steam-driven (phreatic) eruption occurred at Krafla prior to the effusive fissures of Mývatn Fires (1724-29): trigger of the eruption and cause for its location far outside the main eruptive fissures, are unknown. In this light, the recent findings from the IDDP-1 - a rhyolite melt at about 2 km depth under Krafla Caldera, and a conductive boundary layer (CBL) separating the magmatic source from the overlying hydrothermal system - raised a key question: If the intrusion formed during the last Krafla Fires eruption (1975-84), why did it not produced any explosive eruption (as *Vití*)? Past work suggests that rock's permeability in particular, determines whether overpressurized fluid may either fragment the surrounding rocks or escape from it via effective outflowing. A level such as the CBL, which permeability is undefined, may represents a prime lithological barrier above the rhyolite magma.

The research proposed here aims to the understanding of magma/hydrothermal systems and its implications for the potential volcanic hazards, same as in the scientific program suggested for the KMDP-drilling project. Two main synergetically interlinked objectives can be named for this proposal: i) constrain the resilience and response of the CBL to *P-T* perturbations such as rapid/step decompression (e.g. natural or induced by exploitation), or slow-to-rapid heating (magma intrusion), and ii) constrain the time-scale for which the CBL's changes from having a deforming (resilient) behaviour to a brittle response (failure). Data and samples from drillings provide a unique opportunity to foster our understanding on the role of permeability around magma bodies. We propose to address this knowledge gap by combining a new rock datasets from the KMDP drilling with physical laboratory decompression-explosion experiments. Using the world's largest volcanic shock-tube, we will simulate possible scenarios as the CBL responses to controlled rapid decompression, as well as to rapid and slow heating processes.

ICDP

Variations in the Dead Sea sediment record during extreme hydroclimatic changes

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The Dead Sea is a terminal lake of the largest hydrological system in the Levant, covering the boundary between the sub-humid Mediterranean and the hyper-arid Saharo-Arabian climate zones. Thus, even small shifts in the distribution of these climate zones can be documented in the Dead Sea lake sediments. Particularly the lake level of the Dead Sea is sensitive to climatic changes, especially to variations in the amount of precipitation and evaporation. Precipitation in the Dead Sea watershed is primarily provided by seasonal rainstorms associated with eastern Mediterranean synoptic systems and occasionally also by the Active Red Sea Trough and the Cyprus low, which often cause local and regional flash floods.

In this project sediment deposits from different sites in the Dead Sea area are examined in regard to event sedimentation processes during periods of major hydroclimatic changes. In particular, we focus on the last deglaciation and Holocene to investigate variability in seasonal precipitation and frequency of extreme floods. The studied sediment deposits encompass (1) core 5017-1-A of the ICDP Dead Sea Deep Drilling Project, (2) the uppermost Lisan Formation and (3) a new profile obtained in the Ein Feshkha gully system. At all sites a combination of detailed microfacies analyses, XRF element core scanning, organic carbon, carbonate and stable oxygen and carbon isotope analyses is applied.

At the termination of the last Glacial the lake level of the Dead Sea dropped from its highest level by ~250 m, driven by major climatic changes and related re-organisation of atmospheric circulation pattern. We will investigate the last ca 1000 years of the high-stand Lisan sediments, aiming at searching for early signs of hydroclimatic change before the onset of major lake level drop at ~14.5 ka BP. Therefore, we will compare the marginal sediment facies outcropping in the Masada section with the deep lake sediments of core 5017-1-A. The records are correlated using distinct marker gypsum layers. Due to the lake level drop, the Lisan outcrop sediments terminate at ~14.5 ka, so that the time period of lake level decline is only recorded in the deep lake sediment record.

Core 5017-1-A obtained a unique lacustrine sediment record from the deepest part of the northern Dead Sea Basin. Here, we analyze the annually laminated (varved) sediments of this core between 88.5-99.2 m core depth (ca 16.5-11 ka).

In the Masada outcrop, we study the topmost varved sediments between ~28.1 m and ~29.3 m, spanning about 14.5-15.5 ka, before the Lisan Formation terminated due to the falling lake level.

Holocene rainfall and flash flood variability will be investigated in a new sediment profile obtained in the Ein Feshkha erosional gully system. This new profile became exposed in the last two decades due to incision caused be the recent rapid fall of the lake level of ~1m per year. The Ein Feshkha site is located at the northwestern shore of the DS and is considered a suitable record representing mainly Mediterranean rainfall. The sediment record from this site will be compared with the published data from Ein Gedi located farther south on the western shore of the DS. This will allow tracing possible Holocene changes in the behavior of the strong precipitation gradient from North to South. The new Ein Feshkha sediment profile encompasses ~10 m that are assumed to span the last ca 7-8 millennia.

ICDP

The role of hydrothermal fault zones in the lower oceanic crust: Evidence from Wadi Gideah (OmanDP drill site, Samail ophiolite, Oman)

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Hydrothermal circulation and alteration within the oceanic crust are critical processes for the exchange of mass and heat between the solid earth

and the oceans. Although there is good knowledge about how and where shallow hydrothermal circulation occurs, there remain significant shortcomings in our understanding about the geometry and intensity of deep hydrothermal circulation through the lower oceanic crust, as these systems cannot be examined in-situ at active spreading ridges.

Here we present a petrographic and geochemical field study of a hydrothermal fault zone located within the deep layered gabbro section of the Oman ophiolite [1], targeted by the GT1 drill site of the ICDP co-funded Oman Drilling Project. Field observations reveal a one-meter thick normal fault comprising weakly foliated chlorite±epidote rocks with disseminated pyrite and chalcopyrite, which surround heavily altered gabbro clasts. This fault zone offsets a coherent series of layered gabbros and is oriented subparallel to the sheeted dikes that crop out to the south of Wadi Gideah. Gabbro in both hanging and footwall of the fault is altered and abundantly veined. As inferred by experimental studies [2] and petrographic observations sea water related hydrothermal alteration of gabbro follows two reactions: (I) clinopyroxene+fluid => tremolite±actinolite, and (II) clinopyroxene+plagioclase+fluid => chlorite. Epidote if present, is partially growing into open cavities. Chlorite thermometry reveals formation temperatures of about 275°C within the walls and roughly +50°C more in the fault rock. The late stage of alteration mainly forms prehnite and laumontite, mostly along veins.

Whole rock mass-balance calculations reveal strong depletion of alkali elements (Li,Na,Rb,Cs) for all altered rock types. Ni,Cr,Sc and light rare earth elements (LREE) get leached from the layered gabbro. Mn,Co and Fe are leached as well but precipitated into the fault rock which additionally shows a considerable gain in Zn,Cu, and U, pointing towards a strongly charged, reactive fluid composition. The formation of hydrous phases leads to a pronounced increase of water within all fault related lithologies. Based on silica loss and solubility the intensity of alteration requires a fluid-to-rock mass ratio of 450:1 to 900:1.

Strontium isotope whole rock data of the fault rock yield 87Sr/86Sr ratios of ~0.7046, which is considerably more radiogenic than fresh layered gabbro from this locality ($^{87}Sr/^{86}Sr$=0.7030–0.7034), and similar to black smoker hydrothermal signatures based on epidote, measured in Wadi Tayin. Altered gabbro clasts within the fault zone show comparable values with $^{87}Sr/^{86}Sr$ ratios of ~0.7045–0.7050, whereas hanging wall and footwall display values only slightly more radiogenic than fresh layered gabbro.

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ICDP

Imaging North Anatolian Fault Zone in the western Marmara region, Turkey, with a dense local seismic network

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Having a network across the fault is an efficient tool to gain a high resolution image of the fault at depth using several imaging methods. These include imaging the velocity contrast across the fault using fault zone head waves, which arrive at a station before direct P arrivals in case the station is located on the slow side of the fault or using delay times of P arrivals from local events to identify damage asymmetry across the fault, which are of high importance due to their control on properties of earthquake ruptures.

The Ganos fault in the western Marmara region has been activated in a M7.4 event in 1912 and is believed to be a first-order linear and vertical fault that is currently locked down to 15 km depth. A 40-station dense seismic network was deployed in September 2017 at the northeastern part of the Ganos Fault to study the fault-zone geometry at depth. The station layout comprises a higher station density on top of the fault core/damage zone as well a larger inter-station distance away from the fault in different azimuths to ensure both high-resolution fault- zone imaging and good azimuthal coverage for locating local seismic events. Current results from GANOS network show variations in waveforms recorded at different stations, Fault Zone Head Waves and significant reflections, which are useful in identification of the properties of the fault zone as will be presented and discussed.

ICDP

TEPH-ME: CryptoTEPHrochronology in the ICDP Dead Sea deep core as a key to synchronise past hydroclimate changes in the eastern MEditerranean

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In the drought-sensitive eastern Mediterranean region, a better understanding of the past hydroclimate variability is a prerequisite to improve our capability for estimating future changes of the water balance. In this respect, palaeoclimate records from marine or lake sediments provide invaluable information about natural hydroclimate changes. The hypersaline Dead Sea is a key palaeoclimate archive in the south-eastern Mediterranean region, situated at a critical position between more humid Mediterranean climate and the hyper-arid Saharo-Arabian desert belt. The ca. 450 m long ICDP drill core 5017-1, from the deepest part of the Dead Sea, covers the last ~220,000 years, as constrained by radiocarbon, U-Th dating and floating $\delta^{18}O$ stratigraphy methods. Nevertheless, an independent dating method is much needed because (i) radiocarbon dating is limited to the last ~40,000 years, (ii) U-Th dating of authigenic carbonates requires a complex correction procedure with inherent large age uncertainties, and (iii) wiggle matching of oxygen isotope data is not independent and, hence, does not allow the identification of lead- and lag-phase relationships of changing hydroclimate in comparison to other palaeoclimate records.

Tephrochronology has been demonstrated a powerful tool for dating and synchronisation of palaeoclimate records for regional and global comparison. Due to a lack of visible tephra layers in the Dead Sea sediment record, however, direct links with the eastern Mediterranean tephrostratigraphical lattice are still largely absent. Still, the recent discovery of the first cryptotephra ever identified in Dead Sea sediments (the early Holocene S1-tephra from central Anatolia) encouraged the systematic search for tephra time-markers in the ICDP deep-basin core 5017-1, with the aim of improving the chronology of the deep record significantly. Here we present the new TEPH-ME project, which focuses on the identification of widespread and well-dated Mediterranean tephra time-markers in the ICDP sediment cores from the deep Dead Sea basin. Particular emphasis will be set on the last interglacial period (MIS 5e), including its terminations from the penultimate glaciation (MIS 6), and to the early last glacial (MIS 5d-a). This time-window is of major interest to the palaeoclimate community, as it serves as possible analogue to the projected future climate change. Furthermore, it is important to better understand palaeohydrological changes in the southern Levant and its significance as migration corridor for early modern humans leaving Africa during the last glacial-interglacial cycle.

ICDP

Large-scale geoelectrical survey in the Eger Rift (W-Bohemia) at a proposed ICDP fluid monitoring drill site to image fluid-related structures

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The Cheb basin, a region of active earthquake activity in the western Czech Republic, is characterized by intense carbon dioxide degassing along two known fault zones - the N-S-striking Počatky-Plesná fault zone and the NW-SE-striking Mariánské Lázně fault zone. The fluid pathways for the ascending CO_2 of mantle origin are subject of an ongoing International

Continental Scientific Drilling Program (ICDP) project in which several geophysical surveys are currently carried out to image the near-surface geologic situation, as existing boreholes are not sufficiently deep to characterize the structures.

As electrical resistivity is a sensitive parameter to the presence of low-resistivity rock fractions as liquid fluids, clay minerals and also metallic components, a large-scale dipole-dipole experiment using a special type of electric resistivity tomography (ERT) was carried out in June 2017 in order to image fluid-relevant structures. We used static remote-controlled data loggers in conjunction with high-power current sources for generating sufficiently strong signals that could be detected all along the 106.5km long profile with 100m and 150m dipole spacings. Extensive processing of time series and apparent resistivity data lead to a full pseudosection and allowing interpretation depths of more than 1000m.

The subsurface resistivity image reveals the deposition and transition of the overlying Neogene Vildštejn and Cypris formations, but also shows a very conductive basement of phyllites and granites that can be attributed to high salinization or rock alteration by these fluids in the tectonically stressed basement. Distinct, narrow pathways for CO_2 ascent are not observed with this kind of setup which hints at wide degassing structures over several kilometers within the crust instead. We propose a conceptual model in which certain lithological layers act as caps for the ascending fluids, based on stratigraphic records and our results from this experiment, providing a basis for future drills in the area aimed at studying and monitoring fluids.

IODP

Gulf Stream hydrography during the Pliocene/Early Pleistocene: low versus high latitude forcing of the Atlantic Meridional Overturning Circulation

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This project aims to reconstruct the hydrography of the Gulf Stream during the final stages of the closure of the Central American Seaway (CAS) in the Pliocene and Early Pleistocene. Using material from ODP Sites 1006 (Florida Straits) and 1000 (central Caribbean), we test the hypothesis that there was a direct link between CAS closure, warming and increased salinity of the Gulf Stream, and a major strengthening of the Atlantic Meridional Overturning Circulation (AMOC), which led to the present day Atlantic circulation and climate system. An age model for Site 1006 (658 m water depth), a key site positioned ideally at the start of the Gulf Stream, has been established based on the stable isotope compositions of oxygen and carbon in benthic foraminifera. The radiogenic isotope composition of neodymium (Nd) in weakly cleaned sedimentary foraminifera will be measured to trace intermediate water mass mixing and the strength of the AMOC during repeated millennial time scale episodes of CAS closure and re-opening caused by sea level changes. Initial results from ODP Site 1006 show semi-precessional cyclicity in the Nd isotope composition of intermediate depth waters during the early Pliocene, synchronous with changes in mixed layer temperature and salinity (Reuning et al., 2006). Ongoing work includes the reconstruction of upper water column hydrography during the Late Pliocene and Early Pliocene by measuring the stable isotope composition of oxygen measured in mixed-layer and thermocline dwelling planktonic foraminifera. Together, these high resolution records will provide new insights into the importance of low versus high latitude forcings on the strength of the AMOC. This will not only significantly improve our understanding of the mechanisms driving past changes in ocean circulation in response to major tectonic changes but will also provide information relevant to future climate perturbations as a consequence of changing sea surface salinity of the Gulf Stream influencing convection in the North Atlantic and thus the strength of the AMOC.

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ICDP

Pollen- and biomarker-inferred climate at Lake Ohrid in the Early Pleistocene

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Palynological data from the Lake Ohrid DEEP record (southwestern Balkans) corresponding to the Early Pleistocene (Marine Isotope Stages 43 to 35; 1365–1165 ka) confirm that the Ohrid catchment fostered numerous subtropical relict species such as *Carya, Pterocarya, Parrotia, Liquidambar, Taxodium* and *Eucommia* that are now extinct from Europe. Some of these relict trees such as *Cedrus* (up to 40% in MIS 37) along with *Tsuga* (up to 20% in MIS 35) formed important constituents of the interglacial mountainous vegetation of the study area (Panagiotopoulos et al., 2018). Preliminary pollen-inferred quantitative climate reconstructions using the MAT-plant functional type (Peyron et al., 1998) and climatic amplitude methods (CAM; Fauquette et al., 1998) have been tested on the Lake Ohrid DEEP pollen record. Preliminary results show higher than today mean annual temperatures (12 ˚C) and precipitation (1000 mm/year) prevailing in the region during the Early Pleistocene.

In addition to the fossil pollen assemblages, we also used biomarkers to reconstruct independently past temperatures. Mean annual air temperatures (MAAT) assessed from the temperature-dependent configuration of membrane lipids from soil bacteria (glycerol dibiphytanyl glycerol tetraethers, GDGTs), using a calibration from modern lake sediments, show values up to 12 ˚C for MIS 43, i.e. in the range of the pollen-based estimate. However, while following the glacial-interglacial pattern, the GDGT-inferred MAAT values steadily decrease to average values around 8 ˚C in MIS 41, which appear too low. Rather than reflecting actual atmospheric cooling, this trend is most likely due to the diminishing contribution of GDGTs from warmer, exposed soils (i.e. without tree cover) such as wetland soils during the early stages of lake basin evolution. Maxima of aquatic vascular plant, herb (mostly grasses including reeds) and green algae (comprising *Pediastrum* and *Botryococcus* species) concentrations indicate changes in the littoral zone and a higher lake productivity between MIS 43 and MIS 39 and, thus, corroborate the assumption of a gradually expanding lake and decreasing proportions of low-lying littoral and non-forested wetland zones.

First data from compound-specific stable hydrogen isotope analyses of the leaf wax-derived C_{27} *n*-alkane (δ^2H_{C27}, n = 7) show the same range of variability of ~ 30 ‰ as modern precipitation from Mediterranean and northern/Atlantic sources. Similar to the modern circulation regime, dominance of the more depleted end-member suggests predominant uptake of water delivered by Atlantic air masses. A clear relation to glacial-interglacial cycles is currently not apparent. Higher resolution data (in progress) will help identifying the environmental driver of leaf wax δ^2H variability. Preliminary pollen- and biomarker-based findings suggest a warmer and moister climate with a similar source to modern day precipitation in SW Balkans during the Early Pleistocene.

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ICDP

Petrophysical and mineralogical investigation of lacustrine sediments from Lake Junín (Peru)

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Lake sediment studies have become increasingly important in environmental and geological sciences. This reflects both a natural scientific curiosity in the sediment-based reconstruction of the past environmental conditions and also a need to set studies of present day environmental processes in a longer time perspective. The type of sedimentation and geophysical properties of lacustrine lithological units can be investigated with different measurement techniques on core samples and by downhole logging data. By now, downhole logging data are rarely used to contribute to specific scientific research tasks in lacustrine drilling projects, although they allow the determination of lithological, mineralogical and stratigraphic properties of the rocks and sediments especially in sections of lithological gaps or poor core recovery.

The Lake Junín Drilling Project, co-funded by the International Continental Scientific Drilling Program, ICDP, aims to provide a continuous paleoclimate record from lacustrine sediments, and to reconstruct the history of the continental records covering the glacial-interglacial cycles spanning more than 500 kyr (Rodbell and Abbott, 2011). Lake Junín, also known as Chinchaycocha, is a shallow (maximum water depth of 12 m), inter-mountain high-elevation (at 4000 m a.s.l.) lake in the inner-tropics of the Southern Hemisphere that spans 300 km2 in the tropical Andes of Peru (Rodbell et al., 2017). Drill cores were recovered during summer 2015 from three drill sites. After the completion of coring operations, downhole logging measurements were performed in five of the 11 boreholes (1A, 1C, 1D, 2A and 3B) by the Operational Support Group of ICDP.

Two main objectives are addressed in our research project: i) to reconstruct electrofacies logs using the cluster analysis method based on physical properties from downhole logging data, and ii) to link mineralogical composition with interglacial/glacial cyclicity.

For the first objective, the cluster method identifies zones with peculiar petrophysical values in order to group these features into electrofacies classes. Three major groups (carbonate-silt, peat and silt) have been identified with spectrum gamma ray, magnetic susceptibility, and p-wave velocity logs. By the end the physical properties of the clusters are analysed and converted into lithological units according to the lithological information from the visual core description.

For the second objective, we have selected 68 clay-rich samples based on the element distribution of potassium (K) and thorium (Th) from spectrum gamma ray downhole logging data in two boreholes (1D and 3B) at the LacCore repository in Minneapolis (USA), in order to compare and characterize the clay content in the Lake Junín. Qualitative and semi-quantitative mineralogical analyses on randomly oriented bulk rock powder samples were performed by X-ray diffraction (XRD), to identify the different bulk mineral phases that are present in the samples. Mainly quartz, calcite, feldspar and clay minerals have been identified. The clay size fraction (< 2 micron) was separated using a combination of wet-disaggregation, sedimentation and centrifugation techniques. Oriented samples were prepared and analyzed by XRD in air-dried and ethylene glycol state, to identify the individual clay mineralogy. Especially changes in interlayer size and intensity or half-width broadening in the individual clay peaks give information about changes in mineralogical properties. The main clay mineral phases showed illite, smectite, clay mixed-layers and kaolinite in different amounts. Interestingly, some specific samples showed no clay, but only calcite and quartz. Linking the abundance and the lack of the specific clay minerals in core samples with the downhole logging data (spectrum gamma ray and magnetic susceptibility), a relationship between geological history of the lake and climate change processes can be recognized. Consequently, the different mineralogical composition of the sediments, especially the presence or lack of smectite in the clay-rich samples reflects a glacial/interglacial climate cyclicity.

ICDP

Magnetotelluric measurements in West Bohemia to image the local and regional subsurface electrical conductivity structure beneath the Mýtina and Neualbenreuth Maar

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The west of the Bohemian Massif represents the easternmost part of the geodynamically active European Cenozoic Rift System. This region hosts the contact of three tectonic units of the Variscan Belt, i.e. the Saxothuringian, the Teplá-Barrandian and the Moldanubian unit. Since the Upper Cretaceous, the Palaeozoic sutures between the Saxothuringian and the Teplá-Barrandian/Moldanubian units have been reactived and led to the development of the NE-SW trending Eger Rift. Furthermore, the area is intersected by many faults, e.g. the NNW-SSE striking Marianské Lázne fault and the paralleled Tachov fault. The entire region is characterised by ongoing magmatic processes in the intra-continental lithospheric mantle. Active volcanism at surface is not present and active tectonics is mainly manifested by Cenozoic volcanism represented e.g. by four Quaternary volcanoes (Železná hůrka, Komorní hůrka, Mýtina and Neualbenreuth Maar), massive degassing of CO_2 in the form of mineral springs and mofettes as well as the occurrence of repeated earthquake swarms. These phenomena make the Eger Rift a unique target area for European intra-continental geo-scientific research. An interdisciplinary drilling programme advancing the field of earthquake-fluid-rock-biosphere interaction was funded within the scope of the ICDP.

Within the framework of this endeavour, magnetotelluric (MT) measurements are applied to image the subsurface distribution of the electrical conductivity from shallow surface down to depths of several tens of kilometres. The electrical conductivity is a physical parameter that is particularly sensitive to the presence of high-conductive phases such as aqueous fluids, partial melts or metallic compounds. Muñoz et al. (2018) presented 2D images of the electrical conductivity structure along a NS profile across the Eger Rift. They reveal a conductive channel at the earthquake swarm region that extend from the lower crust to the surface forming a pathway for fluids into the region of the mofettes. A second conductive channel is present in the south of the model. Due to the given station setup, the resulting 2D inversion allows ambiguous interpretations of this feature: It can e.g. represent a feeder channel for the Quaternary volcanoes or it resembles the conductivity image of the nearby Tachov fault or the suture zone between the Teplá-Barrandian and the Saxothuringian units. As a 3D inversion is required to distinguish between these scenarios, we conducted another MT field experiment at the end of 2018. Broad-band data were measured at 83 stations along three profiles and some additional stations across the region of the maar, the Tachov fault and the suture zone. We present preliminary results of this new MT data set that form the basis for subsequent 2D and 3D inversions to get a crustal conductivity model of the area.

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IODP

Water mass stratification of the mid-depth Southwest Atlantic during the past 25,000 years

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Improving reconstructions of past ocean circulation is crucial for the understanding of the ocean's role in glacial-interglacial climate changes, e.g. variations in atmospheric CO_2 concentration of more than 80 ppm [1]. The Last Glacial Maximum is a time period that is frequently studied to understand

the ocean circulation under greatly different climate conditions compared to the relatively stable Holocene. However, glacial water mass boundaries and deepwater properties are still uncertain [2,3]. We here reconstruct the water mass provenance of the Southwest Atlantic over the past 25,000 years using Nd isotopes. By this we try to better constrain changes in the boundary of Antarctic Intermediate Water (AAIW) and North Atlantic Deep Water (NADW).

The new Nd isotope records clearly resolve the modern water mass structure that also persisted over the whole Holocene (only with slight changes presumably in the AAIW end member). Contrastingly, the last glacial was dominated by homogeneous Nd isotope signatures at water depths of 1 to 3 km, suggesting a lack of NADW contribution to the Southwest Atlantic. These homogeneous Nd isotope signatures persisted throughout the deglaciation, indicating a small potential contribution of NADW not before the Younger Dryas. The lack of NADW imprint during the last glacial is in strong contrast to benthic $\delta^{13}C$ water mass reconstructions from the same sites [4]. Secondary processes potentially changing the stable carbon isotope values to agree with the Nd isotope reconstructions can be excluded. This hints to changes in the properties of the marine Nd isotopic system. A possible explanation might be associated with increased dust flux from South America changing the end member and/or Nd concentration of AAIW in the southern South Atlantic.

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ICDP

A Late Pliocene paleorecord from the extinct Lake Idaho, USA – a progress report

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A progress report for Year 2 is presented on the current project exploring the potential of a new Plio-Pleistocene sedimentary record from the extinct paleo-Lake Idaho, Western USA, which was drilled as a part of the ICDP "Project HOTSPOT", a.k.a "The Snake River Scientific Drilling Project", 2010-2012. The lacustrine sediment record is mostly calcareous with variable carbonate content from 5-10% to 15-25%. Carbonates are mostly micritic; ostracods were noted in in some intervals but did not appear abundant. Our main study interval is 430-850 m drill core depth; it consists of three units ca. 90 m, 30 m and 240 m thick respectively. The uppermost UNIT III is bedded and exhibits a regular rhythmic alternation of beds of brownish mud (silt) and greyish sandy silt/sand first centimeters to tens of cm thick. The middle UNIT II consists mostly of bedded very fine to medium sand and contains three thin basalt flows. Geochemically, this sediment is characterized by elevated potassium content suggestive of the presence of volcanoclastic material.

The lowermost sediment UNIT I was our key target for testing the potential of the record for paleoclimate studies. As expected, UNIT I consists of fine lake mud of a rather uniform composition. Grain size, texture and the rhythmic carbonate deposition pattern do not differ above and below the 25-m thick basalt layer which splits UNIT I in two parts. This portion of the paleo-Lake Idaho captures the regional response to the major global climate transition from the warm humid Pliocene climate to the initiation of the Northern Hemisphere glaciations and is therefore well worth the in-depth exploration of paleoclimate proxies in future.

The initial study of the 1991 legacy drill core obtained by the US Geological Survey in the marginal part of the Idaho paleobasin indicates that both paleo-Lake Idaho drill cores are correlative and thus the legacy record from the shallow-water site is complementary to the main new drill core record.

IODP

A comparative study on calcite veins from the volcanic sequences of the Izu-Bonin-Mariana forearc and rear arc (IODP expeditions 352 and 351), and the Troodos ophiolite, and their implications for the post-magmatic evolution of supra-subduction zones

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Drill cores recovered during International Ocean Discovery Program expeditions **351** and **352** in the Izu-Bonin-Mariana rear arc and forearc, Western Pacific, and rocks exposed in the Troodos ophiolite, Cyprus, display similar volcano-stratigraphic sequences of the oceanic crust, each subdivided into two geochemically distinct volcanic rock units associated with different stages of subduction initiation. These volcanic units are similarly characterized by pervasive fracture- and fault-controlled fluid circulation and extensive calcite precipitation in veins. Here we present a comparative study on these calcite veins in order to test the hypothesis that these sections of oceanic crust experienced a similar post-magmatic evolution and establish a general model for vein formation within oceanic crust. Based on microtextures, veins from all three locations are subdivided into (1) syntaxial elongate-blocky calcite veins related to extensional fracturing (crack and sealing); (2) blocky calcite veins associated with hydrofracturing and host rock brecciation; and (3) antitaxial fibrous calcite veins that formed by diffusion and crystallization pressure of fibers. Rare earth elements and yttrium, and Sr ($^{87}Sr/^{86}Sr$), oxygen ($\delta^{18}O$), carbon ($\delta^{13}C$) and clumped isotopes ($\Delta47$) of syntaxial and blocky calcite veins indicate mainly low temperature precipitation (<50 °C) from seawater-like fluids. Their $^{87}Sr/^{86}Sr$ ratios intersect the Sr isotope seawater curve within a range of 10 to 20 Ma after respective subduction initiation and indicate mineralization of hydro- and extensional fractures during this time interval. Antitaxial veins formed similarly at low temperatures but varying $^{87}Sr/^{86}Sr$ ratios and $\Delta47$ values suggest variably modified seawater-dominated fluids. These different geochemical signatures are probably related to distinct vein growth mechanisms. $\delta^{18}O$ vs. $\delta^{13}C$ and Y/Ho vs. shale-normalized Eu anomaly plots display specific compositions for the different vein types independently of the location. Low-temperature blocky calcites precipitated within seawater-filled fractures where fluid-rock interaction partly decreased the Y/Ho ratios below the seawater value (<36), possibly due to long fluid residence times. Fast crack and sealing prevented extensive fluid-rock interaction and resulted in seawater-like Y/Ho ratios (up to 87) of syntaxial veins. Antitaxial veins have lower $\delta^{13}C$ compositions than most blocky and syntaxial veins and the highest Eu anomalies (up to 3.3), possibly related to diffusion-related host rock leaching and high-temperature fluid involvement, respectively. These microtextural and geochemical similarities between veins from the Izu-Bonin-Mariana forearc and rear arc, and the Troodos ophiolite demonstrate that these sections of oceanic crust experienced similar post-magmatic phases of fracturing, fluid flow, and veining.

IODP

Extreme W enrichment in highly serpentinised peridotites from Leg 209

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An in depth knowledge of the geochemical cycle of W is crucial for the understanding of e.g. core-mantle interactions and subduction zone dynamics. As W, Th, Ta, and U are all characterized by similar melt incompatibility, their respective element ratios are not affected by magmatic processes and were taken as constant to mass balance the global W geochemical cycle (e.g. [1], [2]). Compared to intensive studies on continental crust and arc related settings, the oceanic crust remains largely unexplored for such elemental mass balances, mainly due to its inaccessibility. Nevertheless, the understanding of W behaviour within various portions of the oceanic crust is critical to infer potential W redistributions during alteration processes; especially as it is known that W appears to be more efficiently removed from deep seawater as the chemically similar Mo [3].

In previous work we demonstrated selective W fractionation from Th, U, and Ta within altered oceanic crust originating from IODP hole 1256D. Additionally, elemental ratios of W/Th, Ta/W and W/U show only little overlap with pristine MORB ratios and indicate even larger W enrichment than reported for arc lavas worldwide that were analysed in previous studies [4]. As the crust drilled in hole 1256D formed at the Cocos-Pacific plate boundary during periods of superfast (< 220mm/a) spreading rates it was possible to sample material from most major alteration types down to the gabbros. In contrast, the samples recovered during Leg 209 from the Mid-Atlantic Ridge between 14°N to 16°N are highly serpentinised mantle peridotites and associated gabbroic rocks from the low oceanic crust. The mantle rocks were exhumed in response to slow spreading rates (c. 25 mm/a). The original crystallization depth is inferred to reach down to 12 – 20km below the Mid-Atlantic Ridge [5].

We present high-precision W-Th-U-Ta data obtained by isotope dilution measurements using mixed U-Th, W-Ta-Zr-Hf-Lu tracers and W double spike with a Thermo Neptune MC-ICP-MS at the University of Cologne. The overall W concentration decreases from c. 250 ppb at 15 – 90 mbsf with a local peak of 750 ppb at 25 mbsf down to 20 – 70 ppb at c. 100 mbsf. These concentrations by far exceed the previously reported concentrations for altered upper oceanic crust (20 – 40 ppb). Additionally, U is enriched compared to Th with U/Th >> 1, whereas other elements like Lu, Hf, Zr, Ta, and Nb are strongly depleted compared to their abundances in altered oceanic crust from hole 1256D, reflecting pristine igneous signatures. Our results underline the fractionation of W form U-Th-Ta, indicating even further enrichment of W in strongly serpentinised portions of oceanic crust.

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ICDP

Results from an ICDP–related deep seismic pre–site survey campaign at Lake Issyk–Kul, Kyrgyz Republic

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Lake Issyk-Kul, located in the Kyrgyz Republic, is one of the deepest and largest lakes in the world. The lake floor is between 600 and 700 m deep. It occupies a deep basin within the Tien Shan mountain range in Central Asia, which is presently one of the Earth's tectonically most active intra-continental mountain belts. Up to 3500 m of terrestrial sediments have been deposited in the basin, including glacial, fluvioglacial, fluvial and lacustrine formations (Fortuna, 1993), of which the oldest are believed to date back to Oligocene – Miocene times (Abdrakhmatov et al., 1993; Chedia, 1986).

Lake Issyk-Kul's sediments comprise a promising record of tectonic events and past climate changes in the Tien Shan region, potentially ranging back to Miocene times. A multichannel airgun seismic dataset acquired in 2013 allows to investigate the lake history further back in time than the previously available single-channel seismic lines with penetration down to ~ 225 m. The 2013 airgun seismic lines indicate seismic penetration of ~350 m in shelf areas and in the basin down to the first multiple (~ 675 m below lakefloor). However, the fully processed seismic profiles show that the acoustic basement has not been reached and the sedimentary infill is likely much deeper.

The sedimentary infill of the lake basin shows a typical turbiditic succession with a flat horizontal lake floor, indicating efficient sediment dispersal in the basin. The tectonic evolution is marked by an anticline structure as well as a significant southward tilt within the basin. Accumulation rates on the crest of the anticline are reduced by ~ 60% on average with respect to the basin. The southwards tilt is gradually and smoothly increasing with depth, comprising a half graben. Subsidence may be estimated from a 145 m depth difference across a 580 m thick turbiditic unit, if ages become available from drilling. In the western part of the lake, the southward tilt is not very distinctive, revealing a more complex tectonic style than just a half-graben. A longitudinal seismic profile shows a basin-filling geometry, with thicker sedimentary units towards the north-east. However, only one such profile is available in SW-NE direction, and details on filling history and tectonics are yet to be defined by an upcoming seismic campaign. Lake Issyk-Kul furthermore revealed extreme lake level variations by >400 meters (Gebhardt et al., 2017). We present an interpretation from the deep basin that also suggests lake level drops, shifts of shorelines and changes in the sedimentary system within the lake, leading to coarser material deposition throughout the basin. The facies succession seems to represent a cyclicity, which may reveal climate forcing on precipitation to evaporation ratio.

We furthermore present the scientific program for a future lake campaign planned for spring 2019. A full set of seismoacoustic data shall be collected, including a higher quality and penetration multichannel seismic dataset than in 2013, multibeam as well as parametric sediment echosounder data. During this 2-weeks campaign, the major goal will be to further understand the depositional setting, controlled by turbiditic activity, delta evolution, lake level variations, and the impact of the transpressional tectonics, which e.g. can provide windows for drilling into older sections, where local uplift reduces sediment thickness. Further we intend to map the deeper lake, down to bedrock, to estimate overall sediment thickness and investigate the transition from mountain slope setting during the onset of deformation in the Miocene towards the modern style lake setting.

In cooperation with the University of Cologne (B. Wagner) we intend to support the sampling of surface sediments and a dedicated coring campaign by collecting a grid of echosounder lines throughout the lake.

The study area is one of the tectonically most active intra-continental areas on the globe, and the sedimentary record contains numerous seismites in shallow lacustrine, beach and fluviatile settings (Bowman et al., 2004), and likely also in the lake basin. Sediment echosounder data will provide further insight into geologic records of earthquakes (e.g. coeval mass transport deposits and megaturbidites) at least for the upper 50 to 80 meters of sediment.

Ultimately we intend to refine the strategies and localization of possible drill sites for an ICDP drilling campaign which is intended to be proposed towards the end of the joint projects from Bremen and Cologne Universities.

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IODP

Influence of the Indian Summer Monsoon runoff on marine productivity during middle Pliocene-early Pleistocene in the northwestern Bay of Bengal

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Abstract

The Indian Summer Monsoon (ISM) is a conspicuous example of the interaction between solid Earth and atmospheric processes, and a key expression of low-latitude hydroclimate. Yet the pattern of variability and its main climatic controls remain elusive beyond the late Pleistocene. In this study, we present results from the core convective region of ISM precipitation in the northwest (NW) Bay of Bengal from site U1445 (17°N, 85°E), drilled during the IODP Expedition 353. Site U1445 offers the potential to track terrestrial-oceanic-atmospheric processes at a relatively high resolution, due to being proximal to one of the largest river systems (Ganges-Brahmaputra), by extracting the strong seasonal signature of the ISM rainfall and fluvial runoff. Here we present a multiproxy approach, using micropaleontological (abundance of marine and freshwater diatoms and phytoliths) and geochemical (biogenic silica, XRF-measured elements) proxies across the

middle Pliocene into the early Pleistocene (4.0-2.5 Ma).

Diatoms are silica precipitating primary producers. At U1445, marine diatoms dominate the siliceous community. Generally, total diatom concentration, biogenic silica and Br/Ti tend to be higher during interglacials. In addition to the marine diatom community, the occurrence of land-derived freshwater diatoms and phytoliths (PHY, silica bodies of grass cells) reflects ISM-mediated precipitation on land, fluvial runoff and wind intensity. The strikingly positive correlation between the total diatom concentration, Br/Ti and PHY content suggests that the input of land-derived nutrients –dependent on ISM rainfall and weathering intensity variations on land– might have played an important role in driving surface water productivity in the NW Bay of Bengal for the interval 4.0-2.5 Ma. Two major increases of total diatom concentration, Br/Ti and PHY content around 3.36 Ma and 3.14 Ma are interpreted to be a two-step strengthening of the ISM runoff and marine silica productivity. These two strengthenings are well mirrored by shifts in the species-specific composition of the diatom assemblage. After 2.86 Ma, the decrease of total diatom and PHY content suggests a weakening of the ISM, before the onset of the Northern Hemisphere Glaciation. We discuss the cyclicity in our records in context with orbital parameters and the robust isotope-based age model.

ICDP

Good times for leaving home? The paleoenvironment of Chew Bahir in south Ethiopia: implications for human evolution, dispersal and technological innovation

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The sediments of the Chew Bahir playa lake in southern Ethiopia were cored down to 280 m depth in the context of HSPDP (Hominin Sites and Paleolakes Drilling Project) and CRC (Collaborative Research Center) 806 "Our way to Europe" projects. The main aim is to reconstruct the paleoenvironmental conditions during the development of anatomically modern humans (AMH) and to test hypotheses about human evolution, dispersal and technological innovation. Based on several dating methods (^{14}C, Ar/Ar, optical stimulated luminescence, chemical fingerprints of tephras) the composite core is shown to cover the last ~600 ka and therefore brackets the time period of important steps in cultural evolution, from Late Acheulean to Middle/Late Stone Age technologies, the origin of AMH, as well as the most recent "Out of Africa" human dispersal events. The multiproxy record of the composite core (e.g., chemical and physical sediment properties, stable C, O and Sr isotope ratios of carbonates, microfossil assemblages and biomarkers) indicates long- and short-time hydroclimatic changes mainly driven by orbital controlled insolation (mostly the Earth's precession ~15-25 ka, but also eccentricity ~90-120 ka). We compare our Chew Bahir data with results from other long marine and terrestrial paleoclimatic records. Here we focus on particularly strong wet and dry fluctuations at Chew Bahir during the last 200 ka to test established hypotheses for human dispersal and technological innovation. The record indicates that at least some of the human dispersal waves have taken place during wetter environmental conditions offering green corridors in East Africa, one of the source regions of our ancestors.

IODP

Exploring microbial sulphate reduction under high temperature on samples from IODP Exp. 370

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Sulphate reduction is the quantitatively most important process in the anaerobic degradation of organic matter in the sea floor. While the effects of elevated pressure and temperature on microbial sulphate reduction have been studied for decades, almost all studies were carried out in hydrothermal systems like Guaymas Basin, whereas sedimentary non-hydrothermal systems did not receive much attention.

Expedition 370 (Temperature Limit of the Deep Biosphere off Muroto) of the Integrated Ocean Drilling Program (IODP) was specifically planned to explore the upper temperature limit of life in a sedimentary system off the coast of Japan (Heuer et al., 2017).

Due to the high heat flow in the area the geothermal gradient is high enough (ca. 100°C km^{-1}) to sample the putative temperature-dependent transition from biotic to abiotic at relatively shallow sediment depth but still sufficiently gradual for the establishment of distinct, thick depth horizons (>10 m) with suitable conditions for psychrophilic (optimal growth temperature range: < 20°C) mesophilic (20-45°C), thermophilic (45-80°C) and hyperthermophilic (>80°C) microorganisms. Site C0023 allows exploring the putative biotic fringe at a relatively shallow depth, but with high resolution of the temperature gradient. Radiotracer measurements of microbial turnover was one of the key aspects of this expedition, and each parameter that can be measured by radiotracer (methanogenesis, anaerobic oxidation of methane, hydrogenase enzyme activity, sulphate reduction) is being measured by a different group that is specialized in this kind of analysis.

Due to several logistical limitations it was decided to carry out those experiments mostly on shore, only for methanogenesis and sulphate reduction a small subset of samples was incubated at their approximate in-situ temperature and atmospheric pressure.

The sulphate reduction rate samples from the on-board incubations were processed at GFZ Potsdam to guide subsequent incubations with radioisotopes. So far, we carried out additional incubations to fill the gaps from the on-board incubations, we also ran further experiments with additions of acetate and methane as electron donors.

The initial results show that sulphate reduction could be detected to over 1000 mbsf. The measured rates agree reasonably well with previous data from ODP Leg 190, Site 1174, which was drilled in close proximity to Exp. 370 site C0023. Rates drop by about three orders of magnitude at a depth of approx. 400 mbsf, which marks the transition from mesophilic to thermophilic communities around 45-50°C. In the mesophilic range the addition of acetate and methane stimulated SRR, but did not show any positive effect at higher temperatures.

The detection of active microbial communities in non-hydrothermal sediments at such high temperatures potentially increases the volume of habitable marine sediments by up to 12% (LaRowe et al., 2017).

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IODP

Abiotic substrate generation and microbial-life signatures close to the temperature limit of life, IODP Expedition 370

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The deep sedimentary biosphere has a vast extent and microbial cells are detected down to record depths of ~2.5 km (Inagaki et al., 2015). Microbial life in deeply buried marine sediment has adjusted to extreme substrate and energy limitation by following strategies such as reducing cell size (Braun et al., 2016), maintenance energies (Hoehler and Jørgensen, 2013) or falling into a state of dormancy until substrates become available (Lomstein et al., 2012). IODP Expedition 370 set out to explore the factors that limit microbial life in marine sediment at a site where temperatures at the sediment/basement interface reach the currently known temperature limit of life at ~120°C (Takai et al., 2008; Heuer et al., 2017). Drilling activities of Exp. 370 took place in the protothrust zone of the Nankai Trough off Cape Muroto, Japan, a location proposed as a site where the zones of catagenesis and living systems overlap and the hydrothermal breakdown of organic matter may provide a direct feedstock for a deep hot microbial biosphere (Horsfield et al., 2006). Yet, it remains unclear at which temperatures microbial activity ceases and the role other non-temperature related parameters play at limiting or sustaining life of the deep biosphere.

Here, we present preliminary organic geochemical data and experimental results that show (i) the currently known downcore extent of microbial life markers at Site C0023 and (ii) the potential for the generation of abiotic substrates, such as methane and acetate that may be used by indigenous microorganism living at the biotic-abiotic fringe. Using multiple reaction monitoring mass spectrometry, we detected a diverse suite of intact polar lipids (with glycosidic headgroups and tetraether and archaeol core lipids) deriving from potentially viable archaea down to 768 meters below seafloor (mbsf). This depth coincides with the bottom of the Décollement zone, where temperatures exceed 90°C (Heuer et al., 2017). To test if the low organic-carbon sediments at Site C0023 have the potential to release substrates that may sustain indigenous microbial communities, we perfomed heating experiments using the hydrous pyrolysis technique (Seyfried et al., 1987). Our high p-T experiments on sediments from four different depths confirmed the generation of abiotic substrates such as methane, C^{2+} hydrocarbon gases, acetate and hydrogen in high amounts often exceeding in-situ concentrations. These results confirm previous investigations (Wellsbury et al., 1987; Parkes et al., 2007) that continuous abiotic substrate formation at high temperatures may fuel a deep hot biosphere within the Nankai Through. If the generated substrates are indeed utilized by the indigenous communities remains to be shown.

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ICDP

Dynamics during solidification of different impact melt zones at the peak ring of the Chicxulub crater, Mexico

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IODP/ICDP Expedition 364 drilled into the peak ring of the Chicxulub crater and cover two thick zones of melt rock. The upper zone have a thickness of at least 36 meters and cover shocked granitoid target rock at a depth of 760 meters below sea floor. The lower zone is enveloped by target rock at a depth between 1220 and 1316 meters below sea floor. Both zones are attributed to an impact melt origin, but differ in terms of layering, chemical composition, fragment content and crystallization. Based on visual inspection of line scans, microstructural and electron microprobe analyses, we compare the structural characteristics of the two melt rock zones to better understand their individual dynamics and solidification.

The upper melt rock zone is layered and can be divide into four subunits, which are from bottom to top: 1) A 9 m thick subunit consisting of two aphanitic, fragment-poor silicate phases displaying mottled texture, evident by devitrified glass and plagioclase grain size. These observations indicate quenching and auto-brecciation during melt solidification. 2) A 16 m thick subunit consists of interlayered silicate and carbonate phases displaying convoluted centimetre-scale folds. While the silicate phase consists of an aphanitic melt rock similar to the subunit beneath, the carbonate represents a secondary phase consisting predominantly of sparitic calcite. Cusp-and-lobe geometry indicates that the silicate phase was more viscous than the pre-carbonate phase during folding and solidification. 3) A 6 m thick melt breccia subunit is composed of a carbonate groundmass covering aphanitic silicate melt rock fragments similar to the silicate phases in the subunit beneath. The texture points to rapid quenching and in situ brecciation. 4) A 5 m thick subunit composed mostly of quenched melt rock fragments set in a brown calcareous matrix. By contrast, the lower melt rock zone consist of silicate melt rock mingled and mixed with strongly brecciated angular to sub-rounded target rock fragments. At the margins to brecciated target rock, melt rock displays large contact strains through viscous deformation, evident by highly stretched fragments.

The structural characteristics of the upper melt rock zone point to rapid quenching of the melt rock, driven by the entrainment of a phase from the top along a perturbation margin during dynamic interaction. Structural observations of the lower melt rock zone suggest entrainment of rapidly cooling silicate melt into brecciated target rock slivers. Thrusting of target rock over surficial impact melt during peak-ring formation explains the observations.

ICDP

Seismostratigraphic analysis of high-resolution 2D data from Nam Co, Tibetan Plateau

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The high-resolution sedimentary archive at Lake Nam Co (SE Tibetan Plateau, China) is estimated to reach back more than one million years, originating from climatic forcing on the hydrologic cycle on the Tibetan

Plateau.

Nam Co sedimentation before 24 ka has not yet been studied, but the analysis of available seismic data provides the opportunity to gain some insight on climate control. As the Tibetan Plateau acts as the 'water tower' of Asia, being the source areas of the seven largest rivers of Asia, a better understanding of the long-term development of the hydrologic system may provide important constraints on future climate change scenarios.

Since 2014, over 800 km of high-resolution 2D multi-channel seismic data have been acquired in Nam Co in the frame of the ICDP project 'Seismic Pre-Site Survey for ICDP Drilling Locations at Lake Nam Co'. This extensive dataset provides information on tectonics and stratigraphy within Nam Co for the entire sedimentary archive.

Own research has revealed that the Nam Co basin has undergone transtension, a combination of transform movement and pre-dominant W-E extension. The latest phase of internal faulting in the lake was initiated around 160 ka. Understanding the tectonic context is important given the interplay between climatically and tectonically induced changes in depositional patterns and rates. The tectonic reconstruction of the basin helps to separate the effect of tectonically created accommodation space on sedimentation rates from variations in sediment input. Lake level is another climatic indicator which is recorded in the lake's stratigraphy. Lake level fluctuations are mainly driven by monsoon variability and the resulting change of the precipitation/evaporation ratio.

Here we show the analysis of the seismic facies in Nam Co and our interpretation with respect to the recorded climatic variability. Seismic facies can be very sensitive to depositional environment changes and sedimentary processes associated with them through variations in geophysical properties, which derive from changes in relative grain size/ water depth. Most important controlling factor will be precipitation patterns of the monsoonal systems and changes on glacial-interglacial periodicities in temperature, insolation/albedo, and evaporation.

This work is a progress report on the attempt to enlighten the role of the Tibetan Plateau on Asian and global climate and to improve predictive capabilities. It significantly contributed through the tectonic and stratigraphic interpretation of seismic data to the proposed ICDP drilling project 'NamCore', which was submitted by Haberzettl et al. in January 2019.

ICDP

Changing flood frequencies under opposing late Pleistocene eastern Mediterranean climates

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Floods comprise a dominant hydroclimatic phenomenon in arid lands with significant implications for humans, infrastructure, and landscape evolution worldwide. The study of short-term hydroclimatic variability, such as floods, and its forecasting for episodes of changing climate therefore poses a dominant challenge for the scientific community, and predominantly relies on modeling. Testing the capabilities of climate models to properly describe past and forecast future short-term hydroclimatic phenomena such as floods requires verification against suitable geological archives.

Dead Sea lake levels reflect mean centennial-millennial hydrological budget in the eastern Mediterranean. In contrast, floods in the large watersheds draining directly into the Dead Sea, are linked to short-term synoptic circulation patterns reflecting hydroclimatic variability. These two very different records are combined in this study to resolve flood frequency during opposing mean climates. Two 700-year-long, seasonally-resolved flood time series constructed from late Pleistocene Dead Sea varved sediments, coeval with significant Dead Sea lake level variations are reported. These series demonstrate that floods cluster into intervals of intense flooding, characterized by 75% and 20% increased frequency above their respective background frequencies during rising and falling lake-levels, respectively. Mean centennial precipitation in the eastern Mediterranean is therefore coupled with significant changes in flood frequencies. These changes in flood frequencies are linked to changes in the track, depth, and frequency of mid-latitude eastern Mediterranean cyclones.

The long sediment cores obtained by the ICDPdrilling from the deep basin of the Dead Sea (DSDDP) provide a unique archive to reconstruct the natural hydro-climatic variability for the last 220 kyrs.

The strong precipitation gradient and extreme environment of the Levante region is exceptionally sensitive to shifts of atmospheric circulation pattern and related hydrological conditions of mid-latitude climatic zones. Investigating origin and mechanisms driving hydrological and environmental changes are emerging challenges for understanding the interplay between climate change and flood frequency. The PALEX ('Paleohydrology and Extreme Floods from the Dead Sea ICDP sediment core') project addresses all aspects of extreme hydro-meteorological events in this region through a joint effort of scientist from Israel, Palestine and Germany. PALEX has been designed as a project within the DFG Trilateral program with the aim of fostering scientific cooperation in the Near East (grant no. BR2208/13-1/-2).

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ICDP

Hipercorig – The new coring tool for sediments in operation

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An innovative, compact, highly mobile rig to recover continuous cores up to 100 m depth of sediment in water depths down to 300 m is currently being released for primarily scientific use. The compact unit will close the gap between rather simple, (i) man-powered piston corers that may only reach depths of a few meters and (ii) heavy-duty drill rigs capable of reaching coring depth well beyond 1.000 m while requiring a professional drill crew and intense, expensive logistics; often not allowing access to places with limited infrastructure.

A crucial issue with today's piston coring is the loss of power along the drill string due to dampening effects as forces are being applied uphole only. This can be eliminated by mounting a down-the-hole (DTH) hydraulic hammer directly above the coring coring assembly. Exactly this is being realized in the design of Hipercorig, thus integrating advanced, inexpensive piston coring with field-proven, hydraulic hammer techniques powered by a high-pressure pump in a modular, mobile system. The device includes a modular barge platform, the complete coring system, iron roughneck, winches, service boat and other auxiliary equipment all transportable in four 20 ft standard containers.

Areas of operation do not only include lakes, estuaries and shallow marine areas, but also land-based utilization in bogs, environmental sites etc. Barge deployment can be achieved manually without docks and heavy cranes due to the modular, low-weight design. Cost of operations will include shipping of the four 20-foot containers, wear parts,, consumables and

maintenance after use as well as personnel cost for a coring expert plus at least two helpers to operate the rig and instrument efficiently and safe.

The acquisition and initial tests were funded by the Deutsche Forschungsgemeinschaft (DFG). Central equipment like the hydraulic hammer-coring assembly had been already successfully tested on Lake Mondsee, Austria in Fall 2016. During summer and fall 2018 the complete barge and drill rig system including its auxiliary parts have been assembled and the hydraulic DTH hammer, rod handling, casing setting system as well as anchor winches were successfully tested. Final decommissioning will include sampling runs and borehole measurements in 200 m deep waters on Lake Constance in April 2018.

Hipercorig will be available for funded scientific projects upon written proposal to the operator at the International Geothermal Centre (GZB) in Bochum. The GESEP Consortium e.V. will serve as an oversight panel to ensure safe operations and fair availability. In addition to scientific coring projects, Hipercorig will also be used for demonstration and training purposes, e.g. GESEP School or other training courses and limited industrial use if availability allows. Interested parties are invited to visit the test site on Lake Constance this spring upon request to the first author.

IODP

Tracking water-rock interaction at the Atlantis Massif (MAR, 30°N) using sulfur geochemistry

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The oceanic lithosphere is exposed to extensive water-rock interaction during and after its formation along mid-ocean ridge spreading centers. Around 25% of ocean floor formed along slow-spreading ridges comprises of serpentinized peridotite as mantle rock is tectonically exposed to seawater. Alteration of peridotite is associated with considerable chemical, physical and mineralogical transformations, and can support microbial communities due to formation of H_2, CH_4, and formate during the serpentinization reaction. In particular, these processes influence the global sulfur cycle due to both biogenic and abiogenic removal of seawater sulfate.

In this study we present the sulfur geochemistry of highly altered mafic and ultramafic samples from the Atlantis Massif located along the Mid-Atlantic Ridge at 30°N. The analyzed samples were drilled during International Ocean Discovery Program (IODP) Expedition 357 and collected during Alvin dives in 2000, 2003, and 2005. Multiple sulfur isotope analyses of sulfide and sulfate phases indicate numerous processes during progressive hydrothermal alteration including incorporation of seawater sulfate, thermochemical sulfate reduction during high-temperature fluid interaction, microbial sulfate reduction, and oxidation of sulfides at high water-rock ratios. Petrological examinations show that high-T fluids mostly post-dated the bulk serpentinization and that these fluid pulses were localized (< 1 dm scale) resulting in a highly heterogeneous mineralogy. Locally, high-T fluid influx took place subsequent to microbial sulfate reduction and oxidation as indicated by geochemical modeling. Overall, this study documents the complex interplay of magmatic processes, fluid-rock interaction and microbial activity that take place during the formation of oceanic core complexes and where mantle rocks are exposed to seawater.

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IODP

Linking the evolution of the active channel-levee system on the Bengal Fan at 8°N to the surface channel pattern on the fan – Integration of results from IODP Expedition 354 Site U1454 and bathymetric data

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The Bengal Fan is the largest submarine fan on Earth covering almost the entire Bay of Bengal. Almost 80% of the eroded material from the Himalayan Mountains is transported towards and stored in the Bengal Fan. The fan provides the most complete sedimentary record of the regional climate and tectonic history covering the time since the fan evolution in the early Eocene until modern times (France-Lanord et al., 2016; Curray et al., 2003).

Therefore IODP Expedition 354 was carried out in February/March 2015 to drill a seven-site, 320 km long transect along 8°N in the Bay of Bengal. In particular, three deep-penetration and four shallow holes were drilled to achieve a complete spatial overview of the turbiditic depositions in time and space.

The Bengal Fan is fed by the Ganges-Brahmaputra river system which recently delivers more than 1 Gt/yr of terrigenous sediment. One third of these sediments is transported to the deep sea fan via a deeply incised shelf canyon by turbidity currents. These currents build-up channel-levee systems, which represent the main architectural elements of the Bengal Fan and play a significant role in this source-to-sink system. They represent high-resolution archives of the erosional history of the hinterland. Consequently the westernmost Site U1454 was drilled through the western levee of the active channel, and provides for the first time an overview on Pleistocene and Holocene fan history as well as the opportunity to study depositional processes along the active channel in hitherto not gained high resolution.

During four cruises with the German Research Vessel “Sonne” (1994, 1997 (2), and 2006) in the Bay of Bengal bathymetric swath-sounder and sediment echosounder PARASOUND were operated continuously. All together data are available from profiles of 23,000 km length crossing the fan in international and Bangladesh waters. These multibeam data were compiled to a single map imaging the surface channel-levee systems. As a major outcome it is obvious that channel avulsions and terminating channels occurred on the middle fan, but also reoccupation of older channel pathways by downfan prograding newer channels happened. All these transport phenomena had a direct impact on sedimentation at drill sites of IODP Expedition 354.

Utilizing an integrated dataset of very-high resolution Parasound data as well as IODP Site U1454 results, the evolution of the active channel-levee system of the Bengal Fan at 8°N was reconstructed. It turned out that the deposition within the levees can be separated into six different phases. Two of these phases show no turbiditic overspilling deposition, but hemipelagic deposition. First dating reveal that these phases may have lasted between 15 – 10 kyrs. However, new dating is in progress and will refine this evolutionary scenario. The phases of inactivity of the active channel at 8°N can be linked to channel avulsions along the active channel further north on the middle fan. More precise dating of the inactivity phases will give a new insight into the timing of channel avulsions but also of the duration of downfan channel progradation until the reoccupation of older channel pathways.

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ICDP

Seismic imaging at a PIER-ICDP fluid-monitoring site in the Eger Rift zone: first results

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The Eger Rift zone (Czech Republic) is an intra-continental non-volcanic region and is characterized by outstanding geodynamic activities, which result in periodically occurring earthquake swarms and significant CO_2 emanations (e.g. Fischer et al., 2010; Weinlich et al., 1998). Because fluid flow and fluid-induced stress can trigger earthquake swarms, both natural phenomena are probably related to each other (e.g. Heinicke et al., 2018; Heinicke et al., 2009; Horálek and Fischer, 2008; Kämpf et al., 1989). The epicentres of the earthquake swarms cluster at the northern edge of the Cheb Basin near the village Nový Kostel (Fischer and Michálek, 2008). Although the location of the cluster coincides with the major Mariánské-Lázně Fault Zone (MLFZ) the strike of the focal plane indicates another fault zone, the N-S trending Počátky-Plesná Zone (PPZ) (Bankwitz et al., 2003). Isotopic analysis of the CO_2-rich fluids revealed a significant portion of upper mantle derived components, hence a magmatic fluid source in the upper mantle was postulated (Weinlich et al., 1999).

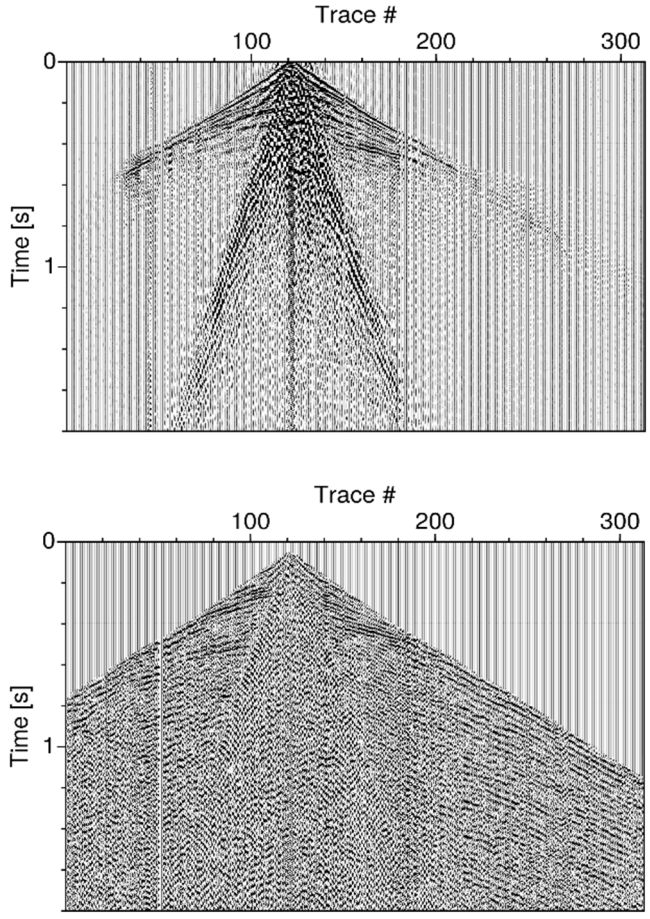

Fig.1: Example of a raw shot gather (top). The same shot is displayed after processing (bottom). A strong near-surface reflection is clearly visible.

Because of these phenomena, the Eger Rift area is a unique site for interdisciplinary drilling programs to study the fluid-earthquake interaction. The ICDP project PIER (Drilling the Eger Rift: Magmatic fluids driving the earthquake swarms and the deep biosphere) will set up an observatory, consisting of five shallow monitoring boreholes (Dahm et al., 2013).

The main geological structures in the survey area are the Cheb Basin, the crustal-scale MLFZ and the potentially seismically active PPZ. The Cheb Basin is a small intra-continental basin which covers the northwestern part of the Bohemian massif. It is situated in the western part of the Eger Rift at the intersection of the SW-NE striking Eger Graben and the MLFZ. It covers mainly granites and Lower Paleozoic series. The basin is deepening towards the east where it is limited by the MLFZ. The thickness of the Neogene sediments of the Cheb Basin is at its maximum less than 300 m and they are underlain by Paleozoic metamorphics and granites.

In preparation for the drilling, the goal of this study is the characterization of the projected fluid-monitoring drill site at the CO_2 degassing mofette field near the village Hartoušov. Therefore, a 6 km long reflection/refraction profile with dense source and receive spacing was acquired. The W-E trending profile crosses the proposed drill site and the surface traces of the MLFZ and the PPZ (see Fig. 1).

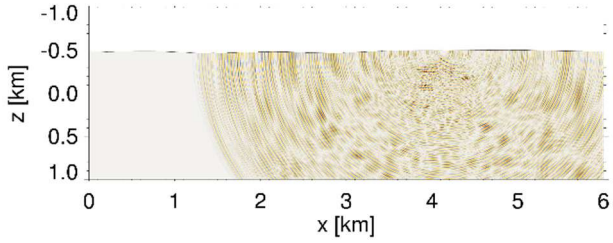

Figure 2: Kirchhoff pre-stack depth migration result for the shot displayed in Fig. 1. The reflection appears at a depth of around 250 m below the shot location.

Up to 1200 Vibroseis shots were recorded with 312 single-component geophones deployed in two spreads along the profile, resulting in maximum offsets of 4 km. The Vibroseis truck (32 tons, 250 kN peak force), owned by the Institute of Geophysics and Geoinformatics, TU Bergakademie Freiberg was used as the seismic source and generated 3-5 sweeps at each source position with a length of 16 s and a frequency bandwidth of 10-120 Hz. The data quality is generally good, although bad coupling of the geophones (due to soft ground) and strong noise from traffic and a nearby factory had a strong impact on the data acquisition. Nevertheless, in most cases the first breaks can be identified for the entire offset and some near surface reflections are visible even in the raw data.

Processing of these recently acquired new data is now ongoing. We applied a first arrival traveltime tomography in order to reveal a detailed near-surface velocity model of the investigation are and to derive a macro velocity model needed for the subsequent pre-stack depth migration approaches. The velocity model shows high variability in the western part of the profile, which was also already visible in the first breaks. The eastern part is donminated by lower velocities reaching a greater depths than in the western part. One very clear near-surface reflection appears in almost every shotgather from the easternmost shot positions (Fig. 1). After depth migration this reflector appears in a depth of about 250 m below surface and could mark the base of the Cheb Basin (Fig. 2).

The goal for further processing is to image potential reflectors within and below the Cheb Basin and to search for indications of the fault systems of MLF and PPZ. Later on, during interpretation of the seismic data, a resistivity model derived from a geoelectrical survey acquired along the same profile line will provide important constraints, especially with respect to the suspected fluid pathways related to the earthquake swarms and the CO_2 emanations.

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ICDP

Anisotropic pre-stack depth migration at the COSC-1 borehole, central Sweden

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A remarkably well preserved representation of a deeply eroded Palaeozoic orogen is found in the Scandinavian Caledonides, formed by the collision of the two palaeocontinents Baltica and Laurentia.

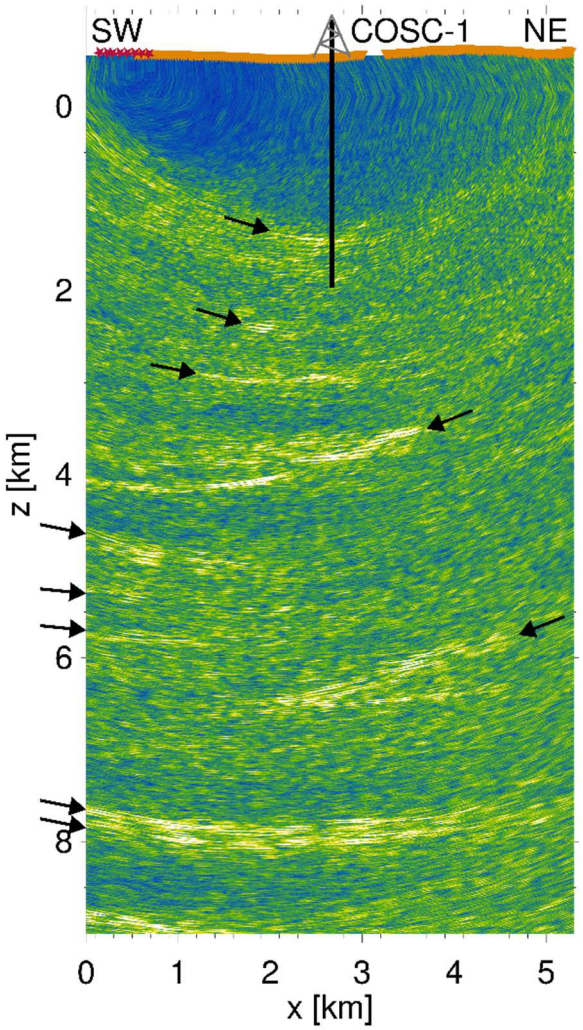

Fig. 4: Anisotropic Kirchhoff pre-stack depth migration result for line 1. Shot and receiver positions are marked in red and orange, respectively. Imaged structures are indicated by black arrows.

Today, after four hundred million years of erosion along with uplift and extension during the opening of the North Atlantic Ocean, the geological structures in central western Sweden comprise far transported allochthonous units, the underlying Precambrian crystalline basement, and a shallow west-dipping décollement that separates the two and is associated with a thin layer of Cambrian black shales. The structure of the basement underneath the décollement is highly reflective and apparently dominated by mafic sheets intruded into either late Paleoproterozoic granites or Mesoproterozoic volcanic rocks and sandstones. These structures, in particular the Seve Nappes (upper part of the Middle Allochthons), the Lower Allochthons and the highly reflective basement are the target of the two approximately 2.5 km deep fully cored scientific boreholes in central Sweden that are part of the project COSC (Collisional Orogeny in the Scandinavian Caledonides) (Gee et al., 2010). Thus, a continuous 5 km tectonostratigraphic profile through the Caledonian nappes into Baltica's basement will be recovered. The first borehole, COSC-1, was successfully drilled to 2.5 km depth in 2014 (Lorenz et al., 2015) near the town of Åre (ICDP drill site 5054-1-A) and revealed a thick section of the seismically highly reflective Lower Seve Nappe. The Seve Nappe Complex, mainly consisting of felsic gneisses and mafic amphibolites, appears to be highly anisotropic.

To allow for extrapolation of findings from core analysis and downhole logging to the structures around the borehole, several surface and borehole seismic experiments were conducted. These included: 1) a high-resolution zero-offset Vertical Seismic Profile (VSP) (Krauß et al., 2018), 2) a spatially limited 3D seismic survey (Hedin et al., 2016) and 3) a multi-azimuthal walkaway VSP in combination with three up to 10 km long surface profiles centred on the borehole (Simon et al., 2017). Here, we use the long offset surface seismic profiles to image the structures in the vicinity of the borehole and below it. Fig. 1 shows the imaging result for one of these profiles.

We applied Kirchhoff pre-stack depth migration, taking into account the seismic anisotropy in the Seve Nappe Complex. We calculated Green's functions using an anisotropic eikonal solver (Riedel, 2016) for a VTI (transversely isotropic with vertical axis of symmetry) velocity model, which was previously derived by the analysis of VSP (Vertical Seismic Profile) and surface seismic data (Simon et al, 2017). We show, that the anisotropic results are superior to the corresponding isotropic depth migration. The reflections appear significantly more continuous and better focused.

The depth imaging of the long offset profiles provides a link between a high-resolution 3-D data set and the regional scale 2-D COSC Seismic Profile and complements these data sets, especially in the deeper parts below the borehole (Fig. 2). However, many of the reflective structures can be observed in the different data sets. Most of the dominant reflections imaged originate below the bottom of the borehole and are situated within the Precambrian basement or at the transition zones between Middle and Lower Allochthons and the basement. The origin of the deeper reflections remains enigmatic, possibly representing dolerite intrusions or deformation zones of Caledonian or pre-Caledonian age. This might be clarified by drilling the proposed borehole COSC-2, which is supposed to penetrate some of these reflectors.

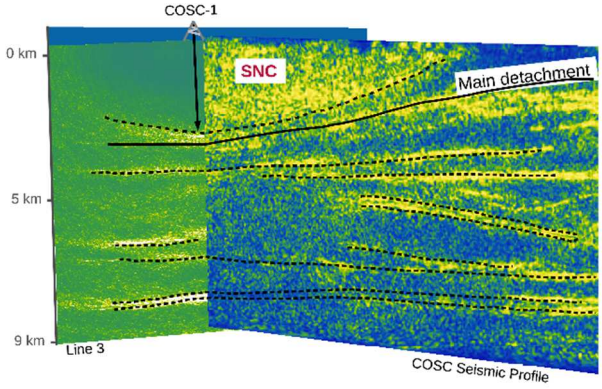

Fig. 5: Comparison between the Kirchhoff pre-stack depth migration result for line 3 and the COSC Seismic Profile (CSP) (after Juhlin et al., 2017) including some interpretation.

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IODP

Reconstructing Neogene Monsoon History and Paleoceanography around India Plans for a German-Indian Site Survey Initiative to support Indian Ocean Scientific Drilling

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The SPADE Workshop, organized in September 2018 in Goa together with the IODP Forum, was intended to initiate a new round of drilling proposals in the Indian Ocean, anticipating the return of D/V Joides Resolution in upcoming years. A recent successful phase of Indian Ocean drilling, following a long absence of IODP in this region, during Expeditions 353 (Clemens, Kuhnt), 354 (France-Lanord, Spieß), 355 (Clift, Pandey), 359 (Betzler, Eberli) and 363 (Rosenthal, Holbourn) particularly focused on the monsoon system, Himalayan weathering and erosion history archived in the Bengal and Indus Fans and paleoceanographic objectives.

For the next phase of drilling around India, six regions are targeted, which include the Andaman Sea (AND), Bangladesh margin (BM), India's northeast margin (NEM), southern margins of India and Sri Lanka (SM), India's northwest margin (NWM) and oceanic bathymetric highs (OBH). The scientific objectives broadly fit into two general categories including (a) research objectives that build on results of previous expeditions, allowing for increasingly focused research questions and objectives as well as (b) important science objectives that have simply not yet been addressed, given the limited amount of Indian Ocean drilling over the years, especially in the modern (IODP) phase.

Main paleoclimatic and paleoceanographic themes identified in the SPADE workshop cover (1) oxygen minimum zones , (2) the warm (and dynamic) Miocene, (3) monsoonal fresh water flux, (4) paleoceanographic depth transects, (5) strong regional heterogeneity in monsoon precipitation and (6) ultra-high-resolution records for direct comparison with land proxy records.

As a follow-up of the workshop, a subgroup of the participants coordinated a data viewing session in January 2019 together with colleagues from IODP India (NCPOR), NIO Goa and the Directorate General of Hydrocarbons (DGH), holding most of the commercial and deep penetrating seismic data. The purpose was to identify potential regions or locations for drill sites, while also gaining a better understanding of the depositional settings of different margin segments.

In a very open and supportive atmosphere, DGH provided full access to seismic data mainly from deeper waters, and in particular to a high-resolution multichannel seismic data set, which had been acquired for EEZ extension. These data were of particularly high quality and turned out to be suitable for indentifying 25 preliminary drill sites on seismic screenshots.

As most of the sites are located on only one low frequency seismic line, further understanding of the regional deposition is required as well as a grid of lines in the vicinity to ensure recovery of continuous sedimentary successions. Accordingly it had been decided that with strong support from the Indian side, German participants intend to submit a shiptime proposal for R/V Sonne to collect multichannel seismic data with the five times higher resolution of the Bremen seismic equipment.

Sites of highest priorities, positioned at the western Indian margin as well as around Sri Lanka are targeted for a sampling and seismic campaign, which will be organized in close cooperation with and with active participation of Indian colleagues.

ICDP

Flow cytometry for purification of fossil pollen from Lake Van for AMS radiocarbon dating – a new approach

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Lake Van, situated on the semi-arid and highly climate-sensitive high plateau of Eastern Anatolia, is one of the most comprehensive continental climate archives in the Near East. A multidisciplinary project, based on sedimentary cores recovered from the Ahlat Ridge in the center of Lake Van, steadily reconstructs paleoclimatic changes as well as sedimentological and geological evolution in the catchment area of Lake Van.

The precision of data analyses is notably dependent on the classification of the results in the relevant chronostratigraphy. Besides some datings on volcanic deposits, the chronology of Lake Van is predominantly formed by climatostratigraphic alignments to other Quaternary archives. In case of the Holocene annually laminated sediments can be considered additionally for the construction of a varve chronology. However, these measurements only allow a relative age estimation of the deposits. For the calibration of Lake Van's lithological ages various absolute datings by radiometric analyses are required, which are infrequent especially for the Holocene.

AMS Radiocarbon dating of terrestrial plant-remains is a traditional radiometric method for age estimations of lake sediments. But the absence of sufficient large plant macrofossils required for AMS dating outlines the limitation of this application. Alternatively pollen samples seem to be suitable for radiocarbon dating due to their ubiquitous presence in sedimentary archives. Nevertheless, their isolation and purification without significant contamination is still challenging. Flow cytometry offers the possibility to separate huge quantities of pollen in a short period of time and therefore is a highly promising alternative to remove contaminants and generate pure pollen samples from heterogeneous sediments.

In this study we present an improved approach to separate sufficient quantities of pollen by flow cytometry required for AMS radiocarbon dating. We were able to generate reliable radiocarbon ages of purified pollen samples extracted from Lake Van samples. Nevertheless, the isolation of separate pollen populations without contamination of foreign particles remains difficult. Here a strong relation between the sediment composition or the sediment's organic matter, the quality of the pollen isolation, and the AMS dating becomes apparent.

Our results demonstrate the importance to further increase the efficiency of the chemical pretreatment and flow cytometry. It is necessary to adjust the processing steps to the pollen concentration and the pollen spectra expected for each individual sample to improve the quality of the separation procedure. In consequence, dating of enriched pollen samples offers a robust contribution and independent time control of existing age estimations of lake sediments in continental records.

IODP

The circulation and carbon burial history of the Early Cretaceous South Atlantic and Southern Ocean

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The Early Cretaceous (i.e. Aptian to Albian) is widely considered a predominantly warm and equable greenhouse climate, but it is also marked by severe perturbations of the global carbon cycle, associated climatic turnovers, and marine biotic crises. Evidence for multiple episodes of dys- to anoxic conditions in the water column and subsequent deposition of marine organic-rich sediments has been found both on regional and global scales. The breakup of Pangea and the simultaneous emergence of young and restricted ocean basins provided favourable conditions for accelerated biogeochemical turnover rates and enhanced drawdown of atmospheric CO_2 into marine sediments. Several studies have related these evolving basins and their restricted environments to periods of increased black shale formation and carbon burial, with a particular importance of the developing South Atlantic and Southern Ocean.

Here we present a reconstruction of the evolution of ocean circulation in the young South Atlantic and Southern Ocean with a particular focus on the opening of several key marine gateways leading to the transient formation and diseppearance of regional carbon sinks. For this purpose, we tightly combined a new stratigraphic framework obtained for several sites across the South Atlantic (DSDP Sites 361, 327, 511) and Southern Ocean (DSDP Site 249 and ODP Site 693) based on high resolution 13C tuning and a joint physical circulation and biogeochemical modelling approach. We use a physical general circulation model (GCM) to test the sensitivity of regional ocean circulation against the large uncertainties in the geographical and radiative boundary conditions and to verify hypotheses derived from new sea water neodymium isotope signatures extracted from the sediments. The reconstructed circulation history provides the boundary conditions to drive a transient biogeochemical box model that is constrained by new geochemical proxy data and allows the quantification of regional carbon burial and to assess its impact on the global carbon cycle.

Throughout the Aptian-Albian, high atmospheric carbon dioxide concentrations lead to an enhanced hydrological cycle with amplified evaporation over the subtropical shelf areas and subsequent intermediate water formation south of the Walvis Ridge. The resulting salinity driven circulation with prevailing warm and saline subsurface waters in the South Atlantic is balanced by a wind-driven northward advection of cool and fresh southern-sourced surface waters. Prior to 124 Ma, the paleobathymetric position of the Falkland Plateau hindered significant water mass exchange between the South Atlantic and the Southern Ocean. Limited ventilation of the deep Cape Basin promoted marine carbon burial and the periodic expansion of bottom water euxinia. From 124 Ma onwards, the progressive westward drift and subsidence of the Falkland Plateau permitted outflow of South Atlantic Intermediate Water carrying a relatively radiogenic neodymium signature into the Southern Ocean. After 116 Ma, the neodymium isotope signatures of the deep South Atlantic, Southern Ocean and Falkland Plateau converged, indicating the opening of a deep water gateway via the Georgia Basin and enhanced mixing between all sub-basins. As a consequence, black shale deposition ceased in the South Atlantic and Southern Ocean. The proposed circulation history can be reproduced with the GCM by a westward propagating Falkland Plateau within the range of state-of-the-art paleobathymetric and atmospheric CO_2 reconstructions. The opening of the Georgia Basin gateway led to a net export of the dense, saline bottom waters produced in the South Atlantic to the Southern Ocean. Dedicated sensitivity experiments reveal that the observed termination of black shale deposition in the Southern Ocean can only be reproduced with a shallow water connection across the proto-Drake Passage. Both a closed and a too deep gateway significantly reduce the temporal variability of Weddell Sea ventilation thereby providing valuable constraints on the water mass exchange between the Pacific and Southern Ocean during the Early Cretaceous.

ICDP

The deep architecture and magmatic-hydrothermal processes of the Campi Flegrei caldera revealed by 3D seismics to support an amphibian ICDP-IODP effort

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Caldera-forming explosive eruptions are among the most catastrophic natural events to affect the Earth's surface and humankind. The Campi Flegrei caldera (CFc) – situated in southern Italy at the border of the densely populated city of Naples – represents one of the world's most active calderas as proven by ongoing unrest involving considerable ground deformation, seismicity, and hydrothermalism. Such volcanic unrest may be regarded as eruption precursor and, hence, the CFc depicts a maximum volcanic risk area posing an imminent threat to millions of people living in its vicinity with potential global implication (e.g. air traffic disturbances, weather and/or climate changes) in case of a large-scale eruption. Understanding the unrest's mechanisms and their role in the generation of eruptions is of paramount importance for a reliable evaluation of future volcanic hazards and risks. Therefore, the CFc has become subject to a joint approach in the ICDP-IODP programmes, with the overarching scientific objective of understanding the most explosive and dangerous volcanism on Earth related to large collapse calderas.

The CFc covers an area of ~120 km² defined by a quasi-circular depression, partly onshore, partly offshore. To date, it is still under debate whether it originates from only one caldera collapse associated with the Neapolitan Yellow Tuff (NYT, ~15 ka) eruption, or two subsequent caldera collapses associated with the NYT and the preceding, high-impact Campanian Ignimbrite (CI, 39 ka) eruptions forming a nested-caldera complex. Although recent 3D high-frequency (~200 m signal penetration) seismic investigations carried out within the DFG IODP-ICDP priority programmes (Steinmann et al., 2016, 2018) provided architectural evidence for the existence of a nested caldera system, the eruption mechanisms are still largely unknown and further evidence from the deeper caldera section are indispensable for a final verification of the caldera's genesis.

To fill this knowledge gap, an additional 3D low-frequency multichannel reflection seismic dataset (25 m line spacing; 20-200 Hz) was acquired in the submerged portion of the CFc in 2016, providing an outstanding signal penetration in the range of the ICDP-IODP target depth of ~2-3 km and, thus, allowing to image the deep caldera portion. In integration with the preceding 3D high-frequency multichannel seismic studies (up to 1000 Hz, 100-150 m line spacing), this seismic database is unprecedented and represents an ideal IODP-ICDP pre-site survey, thereby holding the potential to substantially advance our understanding of magmatic-hydrothermal processes and the structural setting at large collapse calderas.

The low-frequency seismic data show clear evidence for the existence of a ~2 km wide, arcuate fracture zone (vertical low-amplitude to reflection-free seismic facies) along the southern caldera margin. Following the idea of a so-called leaky caldera fault, as established during a 2017 Campi Flegrei Drilling Magellan Workshop, we propose that this fractured area represents an eruption site of the CI leading to a coeval caldera collapse. The quick ejection and emplacement of the CI deposits could for instance explain the acoustic transparency of the fracture (i.e., venting) zone. As the location and style of the high-impact CI eruption remains strongly debated, this finding contributes significantly to our knowledge on the caldera's genesis and associated eruption kinematics. Moreover, the fracture zone is locally characterized by the presence of incoherent, low-frequency, high-amplitude patches pointing towards the presence of a hydrothermal reservoir at ~1.5 s TWT (~1.3 km). Additionally, the high-frequency data revealed shallow (<40 m) anomalous patches (high-amplitude, reversed phase reflection) along the fractured sector interpreted as fluids. Therefore, we hypothesize that these fluids originate from a hydrothermal reservoir at ~1.3 km depth, migrating along the highly permeable fracture zone to shallower levels. Furthermore, the arcuate fractured area is also associated with post-collapse intrusions (e.g. Mount Dolce Dome) and submarine vents (e.g. Nisida Island) and, thus, may represent a weak, permeable caldera segment, favouring magma ascent. Hence, our results suggest that this zone has a strong control on the post-collapse ascent of both fluids and magma, thereby depicting a key location for the interconnectivity between the surface and the deep magmatic-

hydrothermal system. Therefore, this area may also play an important role during the recent unrest episodes, for instance by acting as pressure release conduits. Since the fracture zone has been prone to the rise of magma, it may represent a favourable site for future eruptions with crucial implications for the hazard and risk assessment.

Overall, this study demonstrated the effectiveness of 3D seismic data in providing reliable constraints on the structural framework and magmatic-hydrothermal processes in (partly) submerged volcanic settings. Our work clearly showed that the submerged portion must be considered to be able to fully understand magmatic, hydrothermal, and volcanic processes at partly marine or lacustrine calderas. Moreover, the achieved imaging of down to 2.9 s TWT (~2.5 km) in the caldera provides an ideal foundation for a precise targeting of relevant ICDP-IODP drill sites (e.g. hydrothermally and magmatically altered zones, complete caldera fill, undisturbed extra-caldera sedimentary succession) as well as for guiding the diverted ICDP onshore drilling into the Gulf of Pozzuoli.

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ICDP

Implications of subsurface basaltic rock alteration on the supply of soluble Fe to ocean surface waters – a study on ICDP site Hawaii

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The processes of subsurface basalt weathering under various environmental conditions and the release of chemical constituents are of great importance for the geochemical cycles between hydrosphere, lithosphere and atmosphere. Basaltic rocks, covering about 60% of the Earth's surface (Nielsen and Fisk, 2010), are Fe rich (up to 15 wt% FeO) and are by far more susceptible to alteration than felsic rocks due to their relatively low SiO_2 content (Wolff-Boenisch et al., 2004). Fe(II) released from primary minerals and glasses during weathering under oxygenated conditions is rapidly oxidized to Fe(III) and precipitated in the form of secondary (mainly amorphous) Fe bearing solid phases. These first weathering products are thermodynamically unstable and transform into more stable and ordered crystalline Fe oxides that decreases their reactivity and hereby also the susceptibility of Fe release to solution (Steefel and Van Cappellen, 1990). The transformation pathway could be altered depending on changing environmental conditions such as the solution chemistry (e.g. freshwater – seawater). Characterization of the type of chemical bonding of Fe in secondary phases thus allows estimations on its reactivity and potential release to the environment. In this context, the ratio of amorphous to crystalline Fe (oxyhydr)oxides, defined as activity of free Fe oxides (Feo/Fed), is often used as an important measure for the progress of weathering and the reactivity of Fe in secondary Fe bearing solid phases (Canfield, 1989; Cornell and Schwertmann, 2003).

Dissolved Fe in the Pacific surface waters was found to increase near the Hawaiian Islands from 0.1 nM to 0.6 nM with a maximum of 1.56 nM close to the Kauai Coast (Brown et al., 2005). Despite the various sources effective for Fe supply to the ocean surface waters (e.g. aeolian dust, hydrothermal activity), volcanic islands comprising fresh, porous, and chemically reactive basaltic rocks are together with their water cycles a potential source for increased Fe release and supply to ocean surface waters. However, their contribution to the global chemical budget of the hydrosphere is poorly understood (Rad et al., 2007; Schopka and Derry, 2012).

The potential for the release of Fe from subsurface basaltic rocks of the Hawaii Scientific Drilling Project Phase2 (HSDP2) drill core was investigated to elucidate the contribution of volcanic islands to the geochemical Fe budget of ocean surface waters. Rock specific parameters possibly governing Fe release such as Fe redox state, the specific surface area (SSA) and connected porosity were determined. Furthermore, a four step sequential extraction with increasing strength of the extractant (from deionized H_2O (FeH_2O) and solutions of citrate bicarbonate (FeCB), oxalate (Feo), and dithionite citrate bicarbonate (Fed)) was applied. With this method we determined the type of chemical bonding of Fe that is a prerequisite for its release from the basaltic rocks. Amorphous and crystalline, free Fe (oxyhydr)oxides were identified by their Feo/Fed ratio.

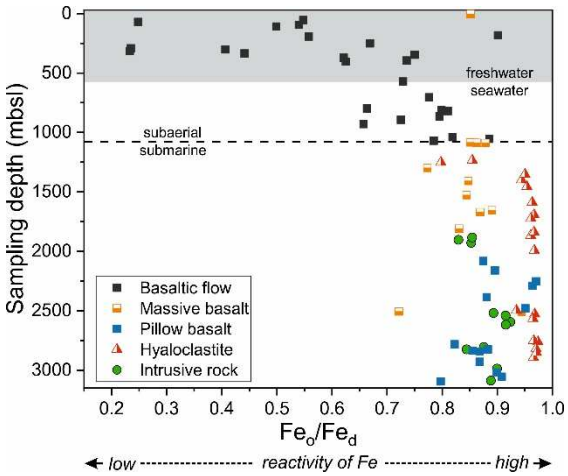

Fig 6: Feo/Fed ratio of different HSDP2 basaltic rocks vs depth of the drill core.
Feo = FeH_2O+FeCB+FeO_x;
Fed= FeH_2O+FeCB+FeOx +FeDCB.
Solid line shows the trend in Feo/Fed with depth. Grey colored area indicates the freshwater saturated zone.

Basaltic rocks with different weathering degree showed elevated Fe(III) contents with Fe(II)/Fetot ratios ranging from 0.82 to 0.42. Highest SSAs, increasing with depth, were observed for hyaloclastites with maximum values of 70 m²/g. Both parameters varied on small scale and depended mainly on the alteration state that is more strongly affected by the fluid chemistry (freshwater ↔ seawater) than by the age of the rocks. Basaltic rocks altered under freshwater dominated conditions showed mean porosities of up to 24 vol.% whereas for seawater altered rocks mean porosities were lower (~6 vol.%).

The sequential extraction revealed that large shares of Fe released during alteration are locally bound in secondary phases such as smectites and Fe (oxyhydr)oxides. Submarine rocks comprise elevated amounts of FeH_2O as well as Feo in comparison to rocks exposed to freshwater. In contrast, the latter showed secondary phases of higher crystallinity (Fed). Aging of secondary Fe phases was suppressed in submarine rocks most probably by the adsorption of anions stemming from the meteoric- or seawater. Here, extractions indicated a strong interaction of silica with secondary phases. Considering the high ionic strength of seawater, a contribution of other anions such as SO_4^{2-}, supressing the transformation from amorphous to crystalline Fe (oxyhydr)oxides is also suggested. Hyaloclastites and pillow basalts showed highest contents of Fe located in free Fe (oxyhydr)oxides with up to 19% and 16% of the total Fe content of the rock, respectively. The amount of released Fe increased in the order massive basalts < intrusive rocks < pillow basalts < hyaloclastites.

Our investigations revealed the presence of (i) highly reactive Fe phases (Feo/Fed > 0.85) within basaltic rocks altered by seawater and (ii) Fe phases of higher crystallinity (Feo/Fed < 0.70) for freshwater altered rocks (Fig. 1). Thus, a potential high Fe release from basaltic rocks altered under seawater dominated conditions can be expected. It is therefore likely that subsurface basaltic rocks of volcanic ocean islands that were altered in the submarine environment are, so far, an underestimated and additional source for increased Fe supply to ocean surface waters. Wheather this phenomenon is typical also for other volcanic ocean islands and seamounts and to clarify the impact of e.g. rock composition, temperature, availability of dissolved silica and age need further investigations. Our findings on the properties of Fe (oxyhydr)oxides in marine systems have likely also strong implications for other geological settings such as Mid Ocean Ridge systems, where large amounts of basaltic rocks are in direct contact with seawater that circulates within the oceanic crust inducing rock alteration and governing hereby mobility of released Fe, also driven by microbial activity (Stranghöner et al., 2018).

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IODP

Evolution of the Deep Western Boundary Current inferred from 231Pa/230Th records

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As part of the Atlantic Meridional Overturning Circulation (AMOC) the Deep Western Boundary Current (DWBC) transports newly formed NADW southward along the North American continental rise representing the most important lower limb of modern AMOC [1]. Resolving its evolution since the last glacial will drastically improve our understanding about the evolution of AMOC and its connection to (paleo)climate. For our investigations we sampled ODP sites 1059 - 1062 located on the Blake Bahama Outer Ridge (BBOR). The BBOR is ideally located within the modern flow path of the DWBC and is therefore well suited to record past changes in geometry and intensity of the DWBC.

We applied the $^{231}Pa/^{230}Th$ kinematic circulation proxy on sediments from the BBOR that form a depth transect from 3000 to 4700 m water depth. In addition to sortable-silt data from the BBOR [2], which provide information mainly about changes in the very bottom current strength, the $^{231}Pa/^{230}Th$ kinematic circulation proxy provides a record of an integrated signal from the overlying water column. In combination with new εNd records from the very same samples, used for identifying the provenance of the prevailing water masses, our $^{231}Pa/^{230}Th$ records provide insight into past circulation states and the strength of the DWBC over the last 30 ka. Climatic key features such as the Last Glacial Maximum (LGM), deglaciation and Holocene in high-resolution are clearly resolvable. Both $^{231}Pa/^{230}Th$ and εNd indicate reduced circulation during the Younger Dryas and Heinrich Stadial 1 and 2 in agreement with records from the Bermuda Rise, including ODP site 1063 [3,4]. During the LGM circulation strength was slightly weaker compared to the deep and strong Holocene circulation but still active. With this new depth transect of combined proxy data we are able to reconstruct the intensity of the DWBC more robustly.

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IODP

Simulating Submarine Fresh Groundwater Preservation Offshore New Jersey

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The existence of submarine fresh groundwater has been recorded at several continental shelves around the world. Different mechanisms have been proposed to explain the emplacement and survival of such fresh water reservoirs; however, the dynamic preservation and lifetime of fresh groundwater in the offshore environment remains an open hydrogeological problem. The New Jersey passive margin represents one of the best documented occurrences of this phenomenon. We study the mechanisms and time scales of fresh groundwater preservation using numerical simulations based on a geologically representative model. Utilizing 2D depth migrated seismic and well data, we built a detailed hydrogeological model, with a vertical resolution of 10 m and a horizontal extent of 127 km. Our model captures the highly heterogeneous shelf environment and accounts for exponential porosity compaction trends measured on **IODP 313** core data. Transient coupled simulations of groundwater flow, heat and salt transport cover the time period from late Pleistocene until today. They indicate that fresh water is preserved preferentially in low-permeability sediments and yield simulated borehole salinity profiles consistent with field observations. Further, our simulations show that fresh water intervals of a thickness of 200 m – 300 m and lateral extent of tens of kilometers may be have been preserved from the Last Glacial Maximum until today. We find that approximately 30 % – 50 % of the initial freshwater volume remains preserved after 15 000 years of transient simulations, depending on the recharge boundary condition. Volume estimates of fresh water stored along passive margins around the world indicate a potentially important unconventional groundwater resource. Our results improve the understanding of submarine preservation of fresh groundwater through an interdisciplinary approach which integrates seismic imaging, hydrogeological modeling and high-performance numerical simulation.

ICDP

Metabarcoding on ancient eukaryotic DNA from Chew Bahir, Ethiopia: Reconstruction of past biodiversity as proxy for environmental change

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Lake-sediment cores provide natural archives of past environmental changes, traditionally analyzed with sedimentological, geochemical and paleontological methods. More recently, samples from sediment cores have also been subjected to molecular DNA analysis, targeting either the living community of soil microbes or remnants of organisms that inhabited the lake, its surroundings and/or its surface sediment in the past. Here we demonstrate the possibility for DNA metabarcoding in the up to 280 m long ICDP sediment cores from the Chew Bahir basin, southern Ethiopian Rift, which cover the last 550,000 years, combining state-of-the-art techniques of environmental genomics and ancient DNA analysis.

Our analyses revealed that DNA quantity and quality in the core is sufficient for both shotgun-sequencing of the entirety of DNA and hybridization-capture based metabarcoding. The latter approach is superior in terms of specificity and sensitivity. Of the sequences that could be assigned to a lineage, the majority were shown to originate from prokaryote microbes, but a substantial number of eukaryote taxa were also identified, among them taxa currently used as proxies in paleolimnological studies (i.e., diatoms), but

also additional taxa informative on past environmental conditions (e.g., fish, insects, mammals, higher plants). So far, a DNA analysis succeeded down to 70m depths, corresponding to about 150,000 years b.p. Further analyses on the deeper part of the core are underway.

ICDP

SUSTAIN drilling campaign campaign into Surtsey volcano – Hydrothermal (bio-mediated) alteration of basaltic tephra

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The International Continental Scientific Drilling Program (ICDP) campaign 5059 drilled 200 m deep into Surtsey volcano in Iceland in August and September 2017. Surtsey formed during volcanic eruptions between 1963 and 1969 and is a unique site for the study of habitability of Mars analog environments with extensive hydrothermal alteration of volcanic tephra. The subsurface samples retrieved during ICDP-SUSTAIN provide a view into microbial processes in very young, pristine, "zero-age" very young basaltic tuff and their preservation in the rock record.

Thirty-three reference samples were collected from the SE-02B and SE-03 cores, adjacent to the samples acquired for microbiological and fluid geochemical analyses, and distributed to science team members for collaborative, interdisciplinary investigations.

The use of structural biosignatures in modern and ancient basalt has recently been heavily debated, due to the difficulties in distinguishing the biotic mediated from the abiotic (Grosch et al. 2014, McLoughlin et al. 2015, Staudigel et al. 2015, French et al. 2016). However, Surtsey's thermal regime spans the limits of life and exceeds it within a well-defined depths interval, making it an excellent study site for investigating the origin and fidelity of biosignatures.

We present first scanning electron microscope and X-ray micro-computed tomography (µ-CT) data on (bio-mediated) alteration processes in the Surtsey tephra. The data provides insight into the nature and rate of biotic alteration of oceanic basalt and,how microbial activity is preserved as biosignatures. Ongoing work will elucidate the nature and timing of microbial colonization of oceanic basalt.

The true 3-D resolved µ-CT datasets document the spatial distribution of alteration phases and pore space evolution during alteration processes and will be made available in a "digital core repository".

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IODP

Onset and modifications in intensity and pathways of water mass exchange between the Southeast Pacific and the South Atlantic with focus on the Falkland Plateau

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The opening of Drake Passage and the Scotia Sea enabled the exchange of water masses between the southern Pacific and the South Atlantic. In this way heat and energy could be transferred between the two oceans. Together with the opening of the Tasman Gateway this allowed the establishment of the Antarctic Circumpolar Current (ACC) thermally isolating Antarctica, which has been considered as one of the major causes for the onset of widespread glaciation. Both tectonic movements within Drake Passage and the Scotia Sea as well as modifications in climate have led to changes in intensity and pathway of the ACC and the water masses flowing within it. The onset of the ACC and those changes have been documented in sedimentary structures deposited on the Falkland Plateau. A study of the sediment drifts shaped by Circumpolar Deepwater, Weddell Sea Deepwater and Antarctic Bottomwater will provide information on modifications of the circulation resulting from tectonic movements and changes in climate. A grid of high-resolution seismic data collected during expedition MSM 81 with RV Maria S Merian will allow the deciphering of the sediment drifts structures as well as their modification and reshaping and the identification and relocation of depot centres.

Additionally, the data will form the base for a site survey package for IODP proposal 862 set on studying the earliest phase of water mass exchange via Drake Passage.

ICDP

Paleoenvironmental indications and cyclostratigraphic studies of sediments from tropical Lake Towuti obtained from downhole logging

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Lake Towuti is a tectonic lake on central Sulawesi, Indonesia. It is located within the Indo Pacific Warm Pool (IPWP), a convection cell, which has major impact on tropical climate and the ability to project its influence on a global scale (Chiang, 2009; De Deckker, 2016). Pre-site surveys using seismic methods and piston cores indicated that sediments in Lake Towuti provide best conditions to obtain a long-term paleoclimate record in this key region (Russel et al., 2014).

During an ICDP-project in 2015, downhole logging equipment of the Leibniz Institute for Applied Geophysics was used at two drill-sites to record a series of chemical and physical parameters (spectral gamma ray, magnetic susceptibility, resistivity, sonic velocity, dipmeter, ultrasonic image of the borehole wall). Continuous lithological logs based only on downhole data were constructed using cluster analysis. Although the spatial resolution of constructed logs is not as detailed as core descriptions, good correlation to core descriptions and differentiation between the upper, lacustrine facies and the lower pre-lacustrine facies (Russell et al., 2016) show that cluster analysis is a powerful tool in giving an instant overview of in situ sediments and determining their physical properties.

Cyclostratigraphic methods in downhole logging can help developing a better understanding of sedimentation rates and thus improving age-depth models for lacustrine sediments (Molinie and Ogg, 1990; Hinnov, 2013; Baumgarten et al., 2015). In case of Lake Towuti, a magnetic susceptibility log from the upper, lacustrine facies (0-98 mblf) was analysed to calculate changes in sediment influx. A careful pre-processing of the data is crucial to secure undisturbed amplitude spectra. This includes the identification and exclusion of event-layers (tephra and turbidite-like mass movement deposits) from the log. Also side effects of those layers to surrounding sediments were diminished from the record.

Results show a dominance of eccentricity cycles, whereupon the longer, 400 ka cycle has to be handled with caution, due to its long wavelength (~37 m wavelength in the ~98 m susceptibility log). Sedimentation rates for certain parts were calculated and complement the preliminarily age model derived from C14- (Russel et al., 2014) and tephra-dating (Deino et al., in prep.).

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ICDP

Was Mediterranean region warmer during the Messinian Salinity Crisis?

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Between 5.97-5.33 Ma kilometres-thick evaporite units were deposited in the Mediterranean basin during an event known as the Messinian salinity crisis (MSC). It is generally accepted that the MSC was a dry period, with higher evaporation than precipitation and runoff. However, how warm or dry the climate was during the MSC is difficult to assess because a modern analogue is missing. Here we reconstructed the mean annual temperatures (MATs) on continental realm and the sea surface temperatures (SSTs) for Mediterranean Sea between 5.55 and 5.33 Ma, using the TEX86 proxy based on branched and isoprenoidal glycerol dialkyl glycerol tetraether (GDGT) respectively. These excellently preserved organic biomarkers were extracted from the reference section of Eraclea Minoa section (from Sicily) deposited during the 'Upper Gypsum', stage 3 of the MSC. The MAT's calculated for the 'Upper Gypsum' Eraclea Minoa indicate values of 19 to 22 ºC, slightly higher than the present day temperatures of 15 to 20ºC on Sicily. Furthermore, we compared the TEX86 derived SSTs with the alkenone based, Uk37 proxy derived SST estimates from the same samples. For the samples where the branched and isoprenoid tetraether (BIT) index was lower than the 0.4 threshold limit we could calculate TEX86 derived SST's as high as 32ºC. These values are slightly higher than the Uk37 derived SST of 20 to 28ºC (the maximum of the available calibration range for Uk37 proxy). These elevated temperature values are up to 10 ºC higher than the once recorded in the past 10 kyr in the Mediterranean Sea using Uk37 proxy (Cacho et al., 2002) and even up to 18ºC higher than those estimated for the last glacial period. Values up 27ºC were recorded during the latest Pleistocene (Herbert et al., 2015) and between 13 and 8 Ma in the Mediterranean region (Tzanova et al., 2015). For the interval between the 8 and 6.4 Ma the Uk37 derived SSTs vary between 19 and 27 ºC, close our calculation for Eraclea Minoa section (20 to 28ºC). However, these calculated SST values should be considered with caution because of the known calibration biases given by, for example, unknown specie of algal alkenone producer or the GDGT distribution in stratified water basins. Regardless the pitfalls that may arise in using the so-obtained absolute values, the two SST estimation methods hint towards much warmer Mediterranean Sea water during the latest phase of the MSC. These warmer values are recorded at times when enriched δD measured on alkenones and δD of long chain n-alkanes indicate both more arid and/or warmer conditions than today for the 'Upper Gypsum' Eraclea Minoa, between 5.55 and 5.33 Ma (Vasiliev et al., under review). We therefore conclude that the climate during the stage 3 of MSC, at the paleogeographic position of Sicily, was drier and warmer that present-day conditions.

ICDP

Glacial-interglacial cycles largely control mass movement deposits in Lake El'gygytgyn

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Lake El'gygytgyn is a bowl-shaped lake of 12 km diameter and 170 m water depth located in Chukotka, NE Siberia (Melles et al., 2011). It was formed 3.6 million years ago by a meteorite impact (Layer et al., 2000). In 2000 and 2003, two pilot studies were carried out that included an extensive seismic survey. Subsequently, the lake was drilled within the framework of the International Continental scientific Drilling Program (ICDP) in 2009, and a 320 m long sedimentary sequence was recovered (Melles et al., 2011).

The lake is prone to frequent mass movement events as observed in 3.5 kHz sediment echosounder data (Niessen et al., 2007). A detailed study of the ICDP deep-drill sediment core revealed 5 different types of mass movement deposits (MMD): Turbidites, grain flow deposits, debrites, slumps, and slides (Sauerbrey et al., 2013). Some of these MMDs have co-genetic origin, e.g. a debris flow may trigger a turbidity current, resulting in a frequent succession of turbidites on top of debrites.

The study presented here focuses on the sediment echosounder data. All MMDs visible in the echosounder profiles were mapped down to a maximum depth of 0.26 s two-way traveltime. Using the age model of the deep drilling core (Nowaczyk et al., 2013), all MMDs were assigned to the corresponding marine isotope stage (MIS). Frequency and accumulated volumes of the individual MMDs within each MIS down to MIS12 were calculated. Both frequency and volumes are strikingly elevated during interglacials compared to glacials. Approximately 3.5 times more material was mobilized as MMDs during interglacials. All in all, this points at a paleoclimate mechanism such as lake-level change with subsequent slope destabilization as the trigger mechanism for MMDs rather than e.g. seismic shaking.

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IODP

Towards a high-resolution orbitally-calibrated Paleogene benthic stable isotope record - new middle Eocene data from ODP Site 1263 cover a key interval

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Exploring and understanding causal relationships of climate change during the past 100 million years is strongly dependent on assembling accurate age models of geological archives. Astronomical age models are key to climatic reconstructions, in particular, because they provide high resolution and outstanding accuracy. Establishing a robust astronomical time scale for

the middle Eocene between 38 and 48 million years ago has previously proved difficult due to a lack of records of sufficient quality. The middle Eocene has thus remained a 'gap' in the coverage of the Paleogene astronomical timescale. Astronomical tuning of bulk stable isotope and XRF core scanning data from ODP Sites 702 and 1263 spanning the middle Eocene gap was recently challenged by interpretation XRF core scan and magneto-stratigraphic records from IODP Sites U1408 and U1410 (IODP Exp. 342, Paleogene Newfoundland Sediment Drifts, Northwest Atlantic). Notably, the duration of magnetic polarity Chron C20r estimated from the Exp. 342 records is almost 500 kyr shorter in duration than in the 2012 Geomagnetic Polarity Time Scale (GPTS) and more than 600-kyr shorter than astronomically calibrated GPTS estimates derived from the interpretation of data from Sites 702 and 1263.

Here we present new magnetostratigraphic as well as high-resolution bulk and benthic stable isotope records from ODP Sites 1051 (Blake Nose, western North Atlantic) and 1263 (Walvis Ridge, South Atlantic) covering the key middle Eocene interval (38–49 Ma, Chrons C18n to C22n). Our new high-resolution benthic stable isotope record from Site 1263 has an average resolution of 5 kyr encompassing the cooling after the Early Eocene Climate Optimum, the Late Lutetian Thermal Maximum, and the Middle Eocene Climate Optimum in unprecedented detail. These records allow further fine tuning of the astronomical time scale for the middle Eocene.

Both bulk and benthic carbon isotope data from Sites 1051 and 1263 document overall dominance of eccentricity cycles in global carbon cycle dynamics that allow construction of new astronomical age models. For example, we can now demonstrate that the composite Exp. 342 records (from Sites U1408 and U1410) are erroneous resulting partly in incorrect orbital cycle interpretations as well as revealing extensive gaps and disturbed intervals especially for magnetic polarity Chrons C18r and C20r.

The new Site 1263 benthic oxygen isotope data reveals a relatively abrupt step of 0.2‰ at 47.12 Ma that coincides with the first appearance for seasonal offshore sea ice in the Arctic. This initial step occurred right after the onset of drift deposits in the Newfoundland Ridge Region and suggests a causal link between a change or at least intensification in ocean circulation and cooling at high latitudes to the point where sea-ice was formed. Our new data point to a major reorganization in the global ocean circulation previously unknown mainly due to wide-spread hiatuses in available deep-sea sections.

ICDP

Investigations on fault zone gases in South African gold mines

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The ICDP-supported **DSeis** project (**D**rilling into **Seis**mogenic zones in deep South African Gold Mines) drilled boreholes in several deep South African gold mines to gain new insights on mining-induced earthquake nucleation and fault slip processes, the status of the stress field at great depths, deep microbiological life and the role and origin of the linked fluids. Two boreholes (817 and 700 meters long) were drilled from a 2.9 km deep mining level of the Moab Khotsong gold mine in order to penetrate into the aftershock plane of the M 5.5 Orkney earthquake that occurred in August 2014 and to retrieve core, fluid, and microbial samples from the seismic active zone.

After drilling, an automated gas analytical system was deployed at depth to monitor the concentrations of specific gas released by the boreholes. The main components of the monitoring system include gas specific sensors for H_2, CH_4, CO_2, O_2, O_3 (ozone), and ^{222}Rn. The gases are monitored at one-minute intervals; the data is transmitted in real time and later correlated with seismic data. Gas monitoring and laboratory measurements of gases will help clarify the process of hydrogen generation (radiolytic, mechanochemical, water reduction on transition metals/metal oxides, or Fischer-Tropsch Type (FFT) reactions), the origin of other gases, and if and how the gases may serve as feedstock for a deep microbial community. Gas samples collected from Hole A revealed a baseline composition of formation gases mainly of CH_4 (62-63 vol-%), followed by He (16-17 vol-%), N_2 (15 vol-%), H_2 (4.8-4.9 vol-%), Ar (1.5-1.6 vol-%), CO_2 (1800-2000 ppmv) and higher hydrocarbon gases. Ratios $CH_4/[C_2H_6+C_3H_8]$ between 10-11 make a contribution of biogenic hydrocarbons less likely, which is typically 2-4 orders of magnitude higher for biogenic gas. The carbon isotope values ($\delta^{13}C$) of C1-C4 hydrocarbons show an unusual pattern, where C_2H_6 is ~ 2‰ and C_3H_6 and C_4H_{10} ~0.8-1‰ depleted in ^{13}C with respect to CH_4. Such distribution of carbon isotopes is atypical for thermogenic hydrocarbons, which become more enriched in ^{13}C with increasing molecular masses (less negative $\delta^{13}C$ values). Carbon isotope distributions in hydrocarbons similar to what we have observed have been reported from Precambrian cratonic shields, e.g. the Canadian and African shield (Young et al., 2017 and references therein) and Fennoscandia (Kietäväinen et al., 2017). An abiogenic source has been proposed for these gases, e.g. by FTT reactions or serpentinization of ultramafic rocks.

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IODP

Ca isotope fractionation during fluid transport through sediment columns - an experimental approach

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Changes in marine pore water chemical composition are important indicators of early diagenetic processes and fluid fluxes. The Ca isotope ratio ($\delta^{44/40}Ca$) is a powerful tool to investigate diagenetic reactions in marine sedimentary porewater systems, as it is sensitive to processes such as carbonate dissolution, precipitation and recrystallization, due to the isotopic difference between dissolved Ca and solid carbonate minerals. It is also affected by ion exchange processes and deep fluid sources (e.g. Teichert et al. 2009; Ockert et al. 2013). In the past decade, the Ca isotope system has been applied as proxy for diagenetic reactions such as $CaCO_3$ dissolution, $CaCO_3$ precipitation (Teichert et al., 2005), ion exchange (Teichert et al., 2009; Ockert et al., 2013) and recrystallization (e.g. Fantle and DePaolo, 2007; Turchyn and DePaolo, 2011). Analyses of Ca isotopes of sediment and pore water samples retrieved during IODP Exp. 320/321 to the Equatorial Eastern Pacific revealed recrystallisation rates and fluid fluxes of deep sea sediment. Fluid movements range between 0.42 and 19 m*Myr-1 at Site U1333 and U1338, in lateral and vertical direction, respectively and recrystallization rates between $0.000013e^{(-t/15.5)}$ and $0.00038e^{(-t/100.5)}$ have been determined, depending on the lithologie, time and column length. IODP Site 1337 is divided by a chert layer at a depth of approximately 254 m, which acts as a diffusion barrier, into two seperated parts (Pälike et al., 2010). In the upper ~240 m the $\delta^{44/40}Ca$ of the pore water is in the range of 1.34 and 1.78 ‰, relatively close to present day seawater values, followed by a prominent decrease to a value of 0.26 ‰, even below the values of the corresponding sediment, and can therefore not be explainend by carbonate dissolution or recrystallisation. A possible process that may explain these observations is isotope fractionation during transport through the sediment. The aim of this study was to experimentally test if transport related fractionation is possible within clay mineral rich sediments and how it depends on the mineralogy and column lengths. We experimentally determined the fractionation of Ca isotopes during diffusion through clay columns of montmorillonite, illite and kaolinite with two different column length from a source solution with 0.32 Mol*l-1 of $CaCl_2$ into a sink reservoir with ultra pure water. The increase of Ca^{2+} into the sink solution was monitored by measuring the conductivity. The sink reservoir was regularly sampled and the $\delta^{44/40}Ca$ determined. Diffusion rates range from 1.04*10-2 to 7.64*10-3 mmol*(l*day)-1, which were in the case of montmorillonite and illite decreasing with increasing column length,

while kaolinite revealed an almost similar value for both experimental setups. The $\delta^{44/40}$Ca of the sink solution was between 0.26 and 1.27 ‰ lighter than the source, increasing towards the values of $\delta^{44/40}$Ca of the source over time. The first Ca passing the columns of illite and montmorillonite was lighter than the source and the fractionation of $\delta^{44/40}$Ca of the fluid released into the sink during diffusion through clay minerals depend on the clay column length and the mineral specific cation exchange capacity, and consequently on the total capacity of the clay columns. Modelling reveals that the transport and isotope fractionation does not follow a simple diffusion approach but rather indicates coupled transport reaction processes at the clay mineral surfaces.

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ICDP

Multi-level online gas monitoring at the Hartoušov mofette: concept and technical setup

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Mofettes are gas emission sites where CO_2 ascends through conduits from as deep as the mantle to the Earth's surface and as such provide natural windows to magmatic/volcanic processes at depth. The primary objective of our research on mofettes is to clarify the physical link between fluid properties, their pathways and swarm earthquakes in the intracontinental Eger Rift belonging to the European Cenozoic Rift system. The Cheb basin terminates the Eger Rift to the West and is known for recurring earthquake swarms. The Hartoušov mofette in the Cheb Basin with a daily CO_2 flux of up to 97 t has been chosen as a key site in the frame of the ICDP project: "Drilling the Eger Rift: Magmatic fluids driving the earthquake swarms and the deep biosphere."

Detailed measurements before, during and after drilling of a 300 m deep well will be carried out to realize possible influences of the drilling activity on the local and regional fluid regime. Our multi-level online approach can provide hints on the origin of temporal variations related to the opening of fault-valves, admixture of crustal fluids to a background mantle-flow or the release of hydrogen during fault rupturing. The suggested state-of-the-art fluid monitoring techniques allow for a high temporal resolution and are completely different from the discrete sampling approach used in the last decades in this region. Gas composition and its isotope signature will be continuously analysed in-situ at different depth levels. Unique in the world, ascending mantle fluids will be tracked along a vertical gradient in a set of drillings from a depth of a few hundred metres to the surface. Using a multi-valve system, it will be possible to collect gas samples from the surface, 30 m, 100 m, and 300 m depth with one set of instruments. Periodically, samples for noble gas isotope analysis will be collected.

IODP

Evolutive methods in cyclostratigraphy: probing for Milankovic cycles in continental (complex) settings

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Cyclostratigraphy is an integral part of many scientific studies on the age and duration of outcrop- and core material from sedimentary geoarchives. Yet, borehole data are not systematically assessed using cyclostratigraphic methods. This has various reasons, including (a) a specific resolution and commonly no possibility to increase data resolution after logging, (b) logging proxy data cannot be connected to the sedimentary environment as easily as core investigations, (c) commonly cyclostratigraphic studies focus on one lithostratigraphical unit, but borehole logs may comprise several (d) some data generated from core material (e.g. stable isotope ratios) cannot be acquired in boreholes directly.

To obtain a reliable understanding of (long) borehole logging datasets, a good understanding of the potential and specifics of relevant (time/depth) evolutive methods in cyclostratigraphy are an essential prerequisite. Therefore, initially we compare the suitability of several evolutive cyclostratigraphic methods using several artificial datasets consisting of modelled Milankovic signals and noise. The principles of spectral moments, and other types of signal characterizations, can be used for initial assessment of signal properties over the entire record. Wavelet analysis and evolutive harmonic analysis (EHA) represent windowed approaches of assessing cyclicity, where wavelet analysis can assess amplitude variations. Evolutive Astronomical Spectral Misfit (eAsm) and evolutive correlation analysis (eCOCO) assess the similarity of power spectra (eCOCO) and significant cyclic variations (ASM) in geological datasets against Milankovic targets. The timeOpt method investigates precession- and eccentricity amplitude modulations and aims at finding a best fit through assessing various sedimentation rates. The astronomical component estimation (ACE) approach can be used to extract Milankovic signals from datasets.

In a second step, we apply methods to several IODP and ICDP datasets, and compare the performance of selected methods in artificial and real cases.

Aim of this work is the comparison of different evolutive cyclostratigraphic methods for an understanding of which methods can resolve specific data challenges. This work represents a first step towards an assessment of method suitability for real cases.

IODP

Experiments on melt-peridotite interaction at crust-mantle boundary: Implications for heterogeneity in the lower crust

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The coherent cores of layered gabbros drilled by IODP Expedition 345 at the Hess Deep Rift validate the Penrose model for interpreting the structure of fast-spreading oceanic crust [Gillis et al. 2014]. One remarkable founding is the occurrence of orthopyroxene as an abundant phase in these deep-level cumulate rocks, which is however unexplainable by crystallization experiments from primary MORB melts and indicates significant modification of melt composition prior to the formation of cumulates. Interaction betwen melt and upper shallow mantle rocks has been proposed as a possible step that may effectly modifies melt composition prior to its migration into the crust [Coogan et al. 2012]. In this study, in combination with analysis of natural samples, we performed melt/rock interaction experiments using a starting glass representing upmoving MORB melt, which is similar to the primitive MORB composition estimated based on bulk crust of Hess Deep, and a natural lherzolite representing mantle rocks. The

experiments were performed at a nominally dry condition using an Internally Heated Pressure Vessels (IHPV), with temperature and pressure consistent to crust-mantle boundary. Three types of experiment were designed. The first type experiments were run at a constant temperature, which serve as pilot for investigating phase stabilities. The second type experiments were run starting from a high temperature (near liquidus) and finished at a lower temperature, in between with slow cooling rate. The third type experiments contain two separated runs, with the first run at near-liquidus temperature for efficient melt-peridotite interaction, and second run at a lower temperature for crystallization using a synthesized starting glass composition identical to the melt produced from the first run experiment. Our experiments show that interaction between MORB melt and peridotite can increase melt SiO_2 content effectively without significantly changing its MgO content, resulting in an evolving trend to orthopyroxene saturation. Particularly, in some experiments, magmatic orthopyroxene was observed coexisting with a large proportion of melt at an early-to-middle magmatic stage. This experimental study demonstrates that melt-peridotite interaction at crust-mantle boundary may be a common scenario responsible for the formation of heterogeneous MORB melts, in which some are close to orthopyroxene-saturation composition with the potential of generating orthopyroxene-bearing cumulates in the lowermost crust.

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IODP

Near lithostatic pore pressures prepare the Nankai décollement for the next megatsunami offshore SW Japan

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Earthquakes along subduction zones cause devastating tsunamis when seismic slip reaches near the trench and displaces the seafloor by tens of meters, as seen in the 2011 Tohoku earthquake (Fujii et al., 2011). To explain tsunamigenic earthquake occurrence, high pore pressure in forearc sediments has been proposed as a mechanism (e.g., Seno, 2002), but direct pore pressure observations along subduction thrusts are still sparse.

Here we provide robust experimental estimates of pore pressure based on consolidation tests. Our samples derive from IODP Site C0023, where the whole accreted and subducted sediment succession was recovered at the seaward edge of the central Nankai Trough accretionary prism offshore Muroto peninsula. Our data indicate pore pressures in the accreted Upper Shikoku Basin facies to outer trench-wedge facies are nearly hydrostatic while samples in the underthrust sequence are overpressured, which is consistent with previous studies. More importantly, our data reveal high excess pore pressure at the top of the décollement. Further hydrogeological modelling based on Cl concentrations suggests that the high excess pore pressure is mainly attributed to pressure translation through recent fluid discharge along permeable faults and overpressured horizon is not confined to Site C0023 but to a considerable areal extent. The high excess pore pressure leads to much lower shear strength than previously thought. Lower shear strength means less energy dissipation and that might explain how a large rupture might not be arrested from propagating to the trench as in the Tohoku earthquake (Faulkner et al., 2011). Hence, the very weak décollement of Nankai Trough subduction zone makes a catastrophic tsunami offshore SW Japan very likely.

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IODP

Hydroclimate change in subtropical South Africa during the mid-Piacenzian Warm Period recorded in fynbos vegetation at IODP Site U1479

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The mid-Piacenzian (mid-Pliocene) Warm Period (mPWP, 3.264-3.025Ma), has become a focus for comparative and detailed numerical climate modelling and data/model comparisons because it is considered an analog for future climate scenarios due to similar CO_2 levels of today with Pliocene estimates. The mPWP hydroclimate of subtropical regions in the southern hemisphere was wetter comparable to the northern hemisphere subtropics as indicated by many palaeoclimate studies, while drier conditions during climate warming are predicted by most models. Therefore, the mPWP hydroclimate reconstruction of subtropical regions especially in the southern hemisphere where the well-dated high-resolution Pliocene palaeorecords are scarce is crucial. It will help us to fill the lack of information in subtropical regions and to fill the lack of paleorecords in the southern hemisphere subtropics. To better understand the hydroclimate change of subtropical South Africa during the mPWP and constrain the underlying forcing mechanisms, a pollen record from IODP Exp. 361 Site U1479 will be investigated for the period between 3.3 and 2.9 Ma at millennial-scale resolution (ca. 3 ka). The preliminary results show that the family of Restionaceae dominates the pollen assemblages, clearly indicating that the main source area of pollen is the fynbos vegetation from the Western and Southern Cape of South Africa. Considering that South Africa is predominantly influenced by southeast trade winds throughout the year, a direct wind transport of pollen from the Cape Province is unlikely. We infer that pollen and spores in sediments of Site U1479 are predominantly transported by the seasonal rivers of the Western and Southern Cape into the ocean, and perhaps also by the strong Agulhas Current to the study site.

ICDP

Forschungsbohrung auf Surtsey Experimentelle Untersuchungen zur Entstehung und der thermischen Geschichte (SUSTAIN)

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Die Entstehung der Vulkaninsel Surtsey vor ca. 50Jahren war ein „benchmark“ Ereignis und machte Surtsey zur Typuslokalität der gleichnamigen Eruptionsform. Surtsey liegt als halb submariner, halb subaerischer Vulkan weitestgehend isoliert, die Eruptionsgeschichte ist wohl dokumentiert, und somit sind Massenbilanzen wie auch mittlere Eruptionsraten verfügbar.

Mit dem Ziel, die noch offenen Fragen zu den Eruptionsprozessen, der jeweiligen Energie-freisetzung bei der Produktion vulkanischer Partikel durch submarine und subaerische Prozesse zu beantworten, wurden Experimente mit repräsentativen basaltischen Schmelzen bei magmatischen Temperaturen durchgeführt: Experimente zu explosiven magmatischen und phreatomagmatischen Fragmentationsprozessen (jeweils unter „trockenen“ als auch „nassen“ Umgebungsbedingungen), wie auch zur thermischen Granulation durch „nichtexplosiven“ Wasser-Schmelze Kontakt. Die Granulationsexperimente wurden in einem Kalorimeter durchgeführt, um die thermische Geschichte der Produkte (Hyaloklastite) zu erfassen. Die Erstellung von Energiebilanzen für die unterschiedlichen Bildungsprozesse ermöglicht die Quantifizierung der jeweiligen thermischen Restenergien. Proben von mehr als 100 Fragmen-tationsexperimenten, die jeweils Typus-Partikel produziert haben, werden mit den natürlich gebildeten Pyroklasten

verglichen, um die relevanten Prozesse zu identifizieren. Ziel ist die Erfassung des geothermischen Gesamtpotentials von Surtsey. In Zusammenarbeit mit der Arbeitsgruppe von PI Bach (Univ. Bremen) läuft ein hydrothermales Experiment, bei dem experimentell erzeugtes „naturidentisches“

Hyaloklastit-Granulat genutzt wird, um die frühe posteruptive thermische Entwicklung zu untersuchen. Zusätzliche Experimente zur Magmen-fragmentation durch hydrothermalen Dampf sind geplant, um dessen Einfluss auf die Eruptionen zu überprüfen.

Nachgereichte Beiträge - *Delayed Abstracts*

IODP

International Ocean Discovery Program Expedition 383 Dynamics of the Pacific Antarctic Circumpolar Current (DYNAPACC)

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The Antarctic Circumpolar Current (ACC) is the world's strongest zonal current system that connects all three major ocean basins of the global ocean and therefore integrates and responds to global climate variability. Its flow is largely driven by strong westerly winds and constricted to its narrowest extent in the Drake Passage. Transport of fresh and cold surface and intermediate water masses through the Drake Passage (cold-water route) strongly affect the Atlantic Meridional Overturning Circulation (AMOC) together with the inflow of Indian Ocean water masses (warm-water route). Both oceanographic corridors are critical for the South Atlantic contribution to AMOC changes. In contrast to the Atlantic and Indian sectors of the ACC, and with the exception of drill cores from the Antarctic continental margin and off New Zealand, deep-sea drilling records of the Pacific sector of the ACC lack information on its Cenozoic paleoceanography.

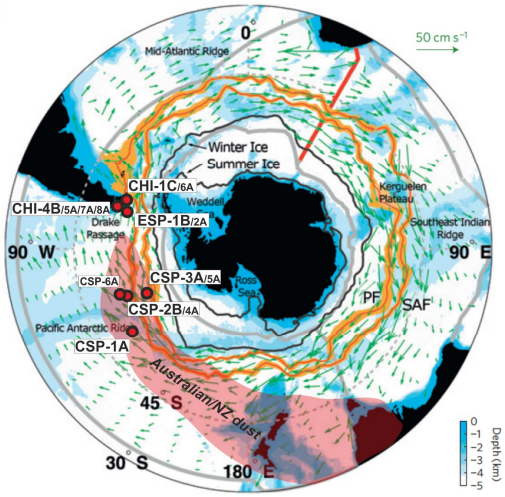

Fig. 1: Map of the ACC (from Marshall & Speer, 2012) and the DYNAPACC drill sites. The climatological positions of the Subantarctic Front (SAF) and Polar Front (PF) are marked in orange, with the thickness of a line representing the variability in the latitudinal position of the corresponding front. Green arrows indicate the observed speed and direction of surface ocean currents as measured by drifters floating at a depth of 15m. Red-shaded area indicates estimated glacial dust supply based on reconstructions from Lamy et al. (2014). Red dots indicate the planned drill sites for Expedition 383; the six primary sites are marked with large font labels, whereas smaller font labels identify the alternate sites.

To advance our knowledge and understanding of Plio-Pleistocene atmosphere-ocean-cryosphere dynamics in the Pacific and their implications for regional and global climate and atmospheric CO_2, International Ocean Discovery Program Expedition 383 proposes the recovery of 180 to 500 m long high-resolution Plio-Pleistocene sediment sequences at (1) three primary sites located on a cross-frontal transect in the central South Pacific (CSP) between the modern Polar Front (Site CSP-3A) and the Subantarctic Zone (Sites CSP-1A and CSP-2B), (2) two sites (CHI-1C and CHI-4B) at the Chilean margin, and (3) one site from the pelagic eastern South Pacific (ESP; Site ESP-1A) close to the entrance to the Drake Passage. The planned sites represent a depth transect from ~1100 m at the Chilean margin (Site CHI-4B) to >5000 m in the Bellingshausen Sea (Site CSP-3A) that will allow investigation of Plio-Pleistocene changes in the vertical structure of the ACC—a key issue for understanding the role of the Southern Ocean in the global carbon cycle. All of the six primary and eight alternate sites were surveyed with seismic lines in 2009–2010 and most recently in 2016. The sites are located at latitudes and water depths where sediments will allow the application of a wide range of siliciclastic, carbonate, and opal-based proxies to address our objectives of reconstructing, with unprecedented stratigraphic detail, surface to deep ocean variations and their relation to atmosphere and cryosphere changes through stadial-to-interstadial, glacial-to-interglacial, and warmer-than-present time intervals.