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**Markus J. Schwab, Jens Kallmeyer,
Sebastian Krastel & André Bornemann (eds.)**

IODP/ICDP Kolloquium 2022

Abstract Volume

Scientific Technical Report STR22/07

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IODP/ICDP Kolloquium 2022

Abstract Volume

Markus J. Schwab, Jens Kallmeyer,
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Scientific Technical Report STR - Data 22/07

IODP/ICDP Kolloquium 2022

Quelle: GFZ

Helmholtz-Zentrum Potsdam - Deutsches GeoForschungsZentrum GFZ

1. – 3. November 2022

Lagepläne

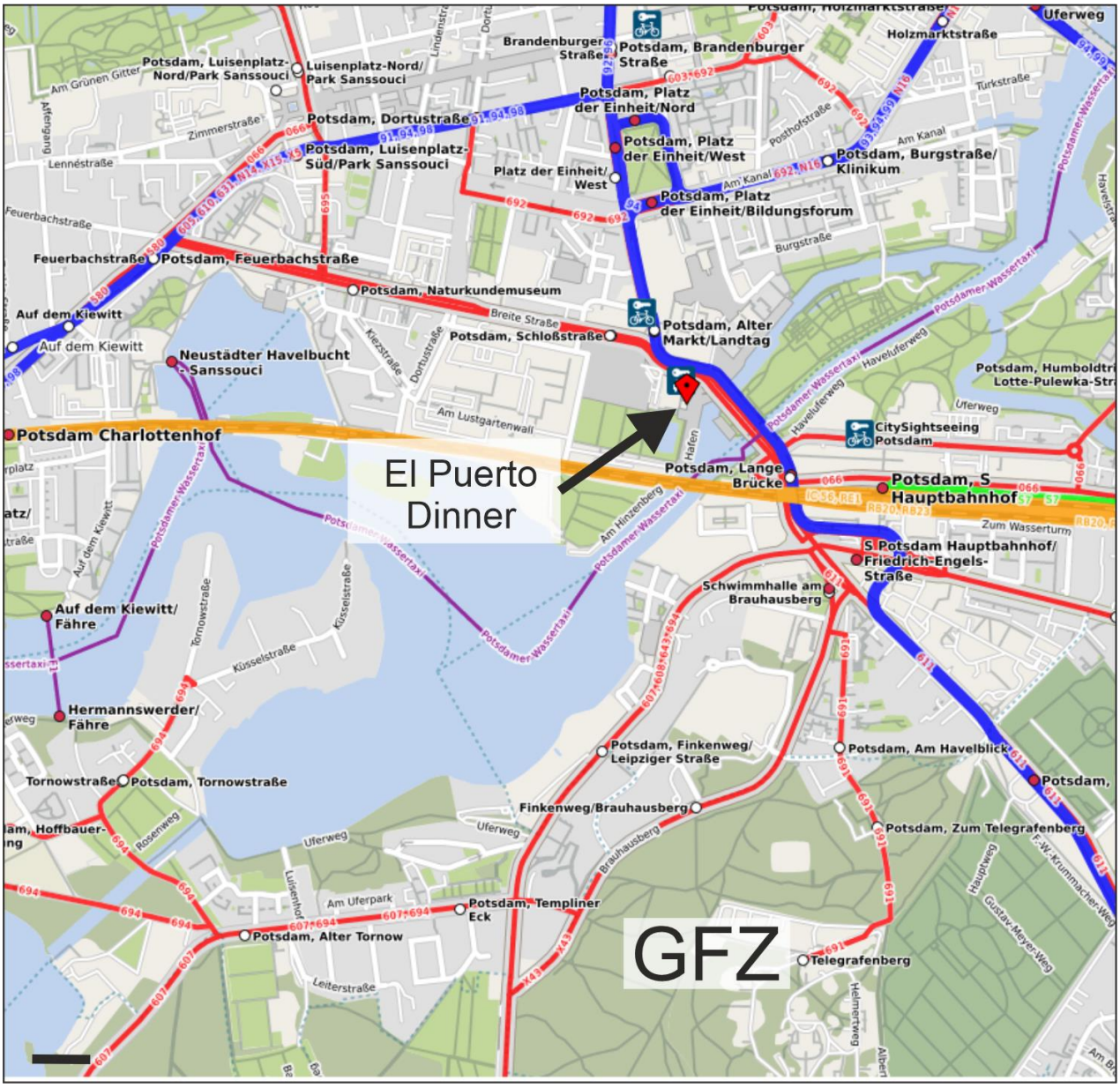
Das Kolloquium findet im Haus H statt.
The colloquium will be held in House H.

Anfahrt zum Kolloquium von Potsdam Hbf

(a) mit dem Bus via Buslinie 691 vom Hauptbahnhof Potsdam zur Haltestelle Potsdam Telegrafenberg (verkehrt alle 30 min zwischen 6:45-9:45 sowie 14:45-18:15)
(b) mit dem Taxi zum Telegrafenberg / GFZ
(c) zu Fuß vom Hauptbahnhof über die Albert-Einstein-Straße (ca. 15 min).

directions to the colloquium

(a) via bus with bus line 691 from Potsdam Main Station (Hbf) to bus stop "Potsdam Telegrafenberg" (only commutes every 30 mins between 6:45-9:45 and 14:45-18:15)
(b) via taxi to Telegrafenberg / GFZ
(c) short walk from Potsdam Main Station (Hbf) via Albert-Einstein-Straße (approx. 15 min).



Weitere Informationen:

- Die Mittagspause am Mittwoch findet ab 13 Uhr in der Mensa im Haus H statt.
- Die Poster sind während der gesamten Zeit des Kolloquiums im Haus H einzusehen.

- Die Icebreaker Party findet im Haus H im Anschluss an das Programm am Dienstag statt.
- Das gemeinsame Abendessen findet am 02.11.2022 um 19:00 im Restaurant El Puerto (Lange Brücke 6, 14467 Potsdam) im Anschluss an das Programm statt.

- Die GESEP School on Scientific Drilling findet im Anschluss an das Kolloquium im GFZ Haus H in den Seminarräumen 1-3 statt..

- Die Zusammenfassungen bzw. Abstracts werden in den Scientific Technical Reports STR, Herausgeber Deutsches GeoForschungsZentrum GFZ, veröffentlicht. Die Reports stehen unter einer Creative Commons-Lizenz (CC-BY-SA 4.0) als offen zugängliche Publikationen im Internet zur Verfügung.

Additional information:

- Lunch break on Wednesday will take place in the canteen of GFZ (House H) starting at 1 pm sharp.
- Posters will be on display in House H during the whole event.

- The “Icebreaker Party” will take place in House H after the program ended on Tuesday.
- Conference dinner will take place on the 2nd November 2022 at 7 pm in the El Puerto restaurant (Lange Brücke 6, 14467 Potsdam).

- The GESEP School on Scientific Drilling will be held after the colloquium in House H seminar rooms 1-3.

- The abstracts will be published as “Scientific Technical Reports STR” by Deutsches GeoForschungsZentrum GFZ. The reports are available under Creative Commons-Licence (CC-BY-SA 4.0) as open access publication.

Tagungsprogramm – *Agenda*

Alle Präsentationen finden im Haus H (siehe Lageplan) statt.

IODP/ICDP Kolloquium 2022 - GFZ Potsdam - 1.-3. November 2022

Programm (Stand 20.10.2022)

Dienstag, 1. November 2022		
13:00	14:00	Registrierung - *Registration*
Beginn Kolloquium - *Beginning of the Conference*		
14:00	14:15	Begrüßung - *Welcome*
14:15	14:35	*Bornemann, A.* **Aktuelle Entwicklung in IODP**
14:35	15:00	*Bohnhoff, M. and Krastel, S.* **Aktuelle Entwicklung in ICDP**
Wissenschaftliche Beiträge zu IODP und ICDP - *Scientific talks related to IODP and ICDP*		
15:00	15:30	*Schäbitz, F.* **Pleistocene climate variability in eastern Africa influenced hominin evolution and dispersal: results from the Chew Bahir record (Keynote)**
15:30	16:30	**Posterpräsentation und Kaffeepause - *Presentation of posters and coffee break***
16:30	16:50	*Petrick, B.* **New Late Miocene climate records raise questions about the traditional narratives of Coral loss and development in the Coral Sea**
16:50	17:10	*Struve, T.* **The role of South Pacific dust provenance changes in Pliocene-Pleistocene climate variability (IODP Expedition 383)**
17:10	17:30	*Vuillemin, A.* **Isotope signatures of diagenetic siderites from Lake Towuti's 1Ma ferruginous archive**
17:30	17:50	*Schubert, F.* **Rapid metabolism fosters microbial survival in the deep, hot, subseafloor biosphere**
Im Anschluss: Posterpräsentation und Icebreaker - Presentation of posters and Icebreaker		

Mittwoch, 2. November 2022		
IODP Expeditionsberichte - IODP Expedition Reports		
09:00	09:20	*Homrighausen, S. (für Hoernle, K.)* **New Insights into Tristan-Gough-Walvis Ridge Hotspot Volcanism from International Ocean Discovery Program Expeditions 391 and 397T**
09:20	09:40	*Uenzelmann-Neben, G.* **Initial results of IODP Expedition 392: Agulhas Plateau Cretaceous Climate**
09:40	10:00	*Longman, J.* **Report - IODP Expedition 396 "Mid-Norwegian Margin Magmatism and Paleoclimate Implications"**
Wissenschaftliche Beiträge zu IODP und ICDP - *Scientific talks related to IODP and ICDP*		
10:00	10:20	*Lehnert, O.* **Drilling the Unknown: Proterozoic igneous and Lower Palaeozoic sedimentary rocks below the Caledonian nappe pile – COSC-2 models vs. reality**
10:20	10:40	*Tanner, D.* **ICDP project "Drilling Overdeepened Alpine Valleys" (DOVE) – status report of boreholes drilled in 2021**
10:40	11:40	**Posterpräsentation und Kaffeepause - *Presentation of posters and coffee break***
Wissenschaftliche Beiträge zu IODP und ICDP - *Scientific talks related to IODP and ICDP*		
11:40	12:00	*Kulhanek, D.* **Pliocene–Pleistocene Antarctic Slope Current modulation of Antarctic Ice Sheet dynamics along the Ross Sea continental shelf break, IODP Site U1523**
12:00	12:20	Lamy, F. **Dynamics of the Pacific Antarctic Circumpolar Current over the past five million years (IODP Expedition 383 - DYNAPACC)**
12:20	12:40	*Dallanave, E.* **Middle Eocene to the early Miocene absolute paleolatitude of northern Zealandia determined from the sedimentary record of IODP Exp. 371 (Tasman Sea)**
12:40	13:00	*De Vleeschouwer, D.* **Multiproxy paleoceanography from Broken Ridge pinpoints the onset of Tasman Leakage at 6.6 Ma**
13:00	14:30	**Mittagspause und Posterpräsentation - *Lunch break and Presentation of posters***

Wissenschaftliche Beiträge zu IODP und ICDP - *Scientific talks related to IODP and ICDP*		
14:30	14:50	*Heubeck, C.* **First results from BASE drilling in the world's oldest well-preserved sedimentary rocks, the Archean Moodies Group (~3.22 Ga), Barberton Greenstone Belt, South Africa**
14:50	15:10	*Rammlmair, D.* **Mesoscale investigation on drill cores. The key to keep track of macro to micro relationships.**
15:10	15:30	*Nikonow, W.* **Combined µEDXRF and LIBS analysis providing information on mineralogical and geochemical variation within magnetitite layers in the Upper Zone of the Bushveld Complex**
15:30	15:50	*Merseburger, S.* **ICDP Oman Drilling Project: Drilling through the crust mantle transition zone - the formation of massive dunites.**
15:50	16:40	**Posterpräsentation und Kaffeepause - *Presentation of posters and coffee break***
Wissenschaftliche Beiträge zu IODP und ICDP - *Scientific talks related to IODP and ICDP*		
16:40	17:00	*Cook, A.* **IODP APL 691: Linking sediment deposition during glacial cycles and methane hydrate occurrence**
17:00	17:20	*Dummann, W.* **The opening of the Equatorial Atlantic Gateway and its impact on the mid-Cretaceous climate**
17:20	17:40	*Jurikova, H.* **A geochemical perspective on the evolution of Dead Sea brines and its link to Eastern Mediterranean hydroclimate (project PRO-HYDRO)**
17:40	18:00	*Müller, D.* **Phases of stability during major hydroclimate change ending the Last Glacial in the Levant**
ab 19:00		***Gemeinsames Abendessen im Restaurant El Puerto (Lange Brücke 6, 14467 Potsdam)***

Donnerstag, 3. November 2022		
Wissenschaftliche Beiträge zu IODP und ICDP - *Scientific talks related to IODP and ICDP*		
09:00	09:20	*Henehan, M.* **Carbon Cycling at the Dawn of the Cenozoic**
09:20	09:40	*Wiese, F.* **The response of terminal Maastrichtian deep-sea echinoids to the Latest Maastrichtian Warming Event (LMWE) and the K/Pg Boundary Event**
New developments in scientific ocean drilling post-2024		
09:40	10:30	*Camoin, G., Lüniger, G. & Bornemann, A.* **New developments in scientific ocean drilling post-2024**
10:30	11:10	**Posterpräsentation und Kaffeepause - *Presentation of posters and coffee break***
11:10	11:30	*Lipus, D.* **Analysis of CO2 driven microbial behaviour and metabolic responses in the geologically active Eger Rift subsurface**
11:30	11:50	*Ohrnberger, M.* **ICDP-EGER pilot seismological 3D-array test site S1: installation, operational status and first observations**
11:50	12:10	*Chen, X.* **Estimating Earthquake Source Parameters in the Sea of Marmara**
12:10		**Posterprämierung und Schlussworte - *Poster Awards and Concluding Remarks***
13:00		***GESEP School on Scientific Drilling: GFZ Potsdam (GFZ Haus H, Seminarräume 1-3)***
<u>Ende:</u> Freitag, 4. November 2022, 16 Uhr		

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Fahrtberichte – *Cruise Reports*

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Fahrtberichte – Cruise Reports

IODP

IODP Expedition 386 – Japan Trench Paleoseismology

Piero Bellanova[1], Aaron Micallef[2,3], Ting-Wei Wu[4,5], Michael Strasser[6], Ken Ikehara[7], Jeremy Everest[8], Lena Maeda[9] & the IODP Expedition 386 Science Party

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The 2011 M_W 9.0 Tohoku-Oki earthquake and resulting tsunami was one of the most devastating catastrophic geologic events in recent history that had major societal consequences. This event was the first of its kind (magnitude $\geq M_W$ 9) to be instrumentally-recorded by offshore geophysical, seismological, and geodetic instruments.

Studying prehistoric events preserved in the geological record is the best way to reconstruct past megathrust earthquakes and to calculate recurrence intervals. Yet, our understanding of giant tsunamigenic mega-thrust earthquakes remains limited and the historical and terrestrial sedimentary records are restricted to a few hundred years. The investigation of deep-sea sedimentary archives with a set of multi-proxy paleoseismological tools allows the detection of past earthquake traces, the reconstruction of the long-term earthquake history, and the delivery of observational data that help to reduce uncertainties in seismic hazard assessment for long return periods.

The Expedition 386 "Japan Trench Paleoseismology" is motivated by the mission to fill the gap in long-term records of giant earthquakes and aims to test and develop submarine paleoseismology in the deep-sea environment of the Japan Trench. Therefore, this expedition aimed to test the concept of submarine paleoseismology in the Japan Trench by achieving the three main scientific objectives: (1) Identify the sedimentological, physical, chemical, and biogeochemical proxies of event deposits in the sedimentary archive that allow for confident recognition and dating of past M_W 9 class earthquakes vs. smaller earthquakes vs. other driving mechanisms; (2) explore the spatial and temporal distribution of such event deposits to investigate along-strike and time-dependent variability of sediment sources, transport and deposition processes, and stratigraphic preservation; and (3) develop a long-term earthquake record for giant earthquakes.

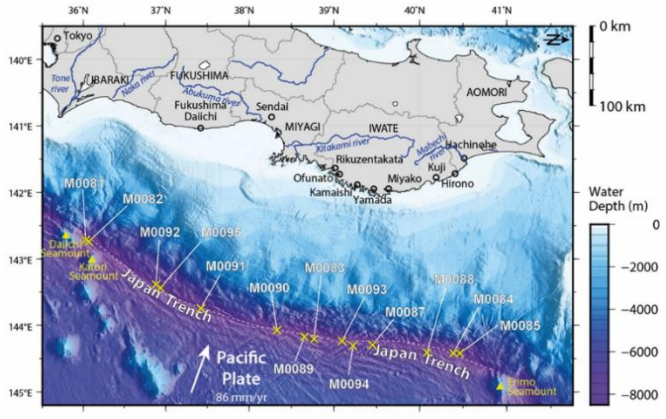

Figure 1: IODP Expedition 386 – Overview Map of the obtained cores in the Japan Trench.

This expedition (R/V Kaimei offshore period: 13th April-1st June 2021) marks the first time giant piston coring (GPC) was used in IODP, and also the first time partner IODP organizations cooperated in jointly implementing a mission-specific platform expedition. In addition, the Onshore Science Party (D/V Chikyu, 14th February-14th March 2022) marks the first (and hopefully last) remote science party due to the ongoing COVID pandemic. We successfully collected 29 GPCs at 15 sites (1 to 3 holes each; total core recovery 832 m), recovering 20 to 40-meter-long, continuous, upper Pleistocene to Holocene stratigraphic successions of 11 individual trench-fill basins along an axis-parallel transect from 36°N – 40.4°N, at water depth of 7,445-8,023 m below sea level. These comprise the first high-temporal and high spatial resolution investigation and sampling of a hadal oceanic trench, which forms the deepest and least explored environment on our planet.

The retrieved cores are currently under examination by the members of the science party. Via a multi-proxy approach the hadal trench sediments are being characterized and dated. Sedimentological, physical and (bio-)geochemical features, stratigraphic expressions and spatiotemporal distribution will be analyzed in detail for proxy evidence of giant earthquakes and (bio-)geochemical cycling in deep sea sediments. Initial preliminary results reveal event-stratigraphic successions comprising several potentially giant-earthquake related event beds, revealing a fascinating record that will unravel the earthquake history of the different along-strike segments that is 10–100 times longer than currently available. Post-Expedition research projects (following the Personal Sampling Party onboard of D/V Chikyu, 15th November – 6th December 2022) will further analyze these initial IODP data sets to: (a) enable statistically robust assessment of the recurrence patterns of giant earthquakes, there while advancing our understanding of earthquake induced geohazards along subduction zones and (b) provide new constraints on sediment and carbon flux of event-triggered sediment mobilization to a deep-sea trench and its influence on the hadal environment.

IODP

New Insights into Tristan-Gough-Walvis Ridge Hotspot Volcanism from International Ocean Discovery Program Expeditions 391 and 397T

Kaj Hoernle[1], Will Sager[2], Tobias Höfig[3], Peter Blum[3] & the Expedition 391/397T Scientists

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2) University of Houston, Texas, USA
3) IODP, College Station, Texas, USA

The Tristan-Gough-Walvis (TGW) hotspot track extends from the Etendeka flood basalts (at ~132 Ma) through the Walvis Ridge and then the Guyot Province to the two active volcanic island groups of Tristan da Cunha and Gough in the southeast Atlantic Ocean (figure 1). The TGW track is complex, consisting of ridges (i.e., Frio Ridge), a plateau (Valdivia Bank), seamounts and guyots (flat-topped seamounts). At the end of the Walvis Ridge, the TGW track splits into two to three subtracks: 1) southern Gough subtrack going to Gough Island, 2) central subtrack, and 3) northern Tristan subtrack going to Tristan da Cunha Island group. The TGW track displays the longest known geochemical zonation of any hotspot track on Earth thus far, extending to ≥70 Ma. An important question is whether the plume contains two distinct geochemical zones (Gough and Tristan), which mix in the central track to give an intermediate composition, or if the Central Track represents a third distinct zone (source) within the plume.

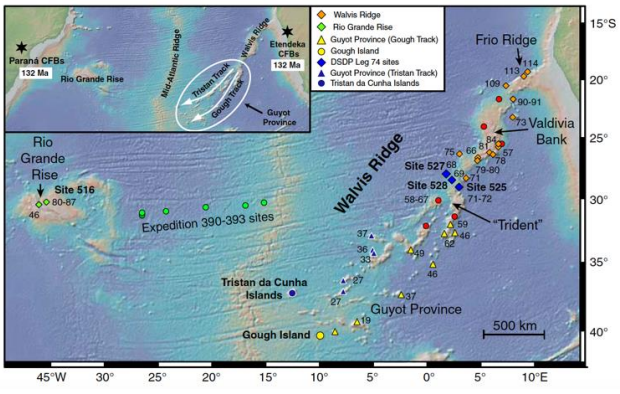

Figure 1: Showing sampling sites preceding IODP Exp. 391 and 397T.

At the beginning of 2022, International Ocean Discovery Program (IODP) Expedition 391 drilled four sites (U1575-U1578) on the TGW track to investigate geochemical zonation and its origin, to determine hotspot paleolatitudes, and to understand volcanic processes that created the edifices (Figure 1:. The main drilling target was the upper volcanic crust at the four sites and a total of 546.9 m of igneous basement and 949.6 m of overlying sediments were recovered. Sites U1575 (Frio Ridge) and U1576-U1577 (Valdivia Bank) recovered both pillow and massive flows, the latter being several meters to tens of meters thick. Site U1575 cores recovered basaltic rocks and the first low-Ti basalts from the Walvis Ridge, similar to low-Ti basalts in the Etendeka flood basalt province in their major element composition. At Site U1576, the composition of basement lavas ranged from basalt to basaltic andesite and included seven pelagic sediment interbeds, implying eruptions interspersed with periods of quiescence. Above basement, the same site produced an apparently continuous section of pelagic carbonates, showing cyclical color variations indicating environmental changes, spanning stages from Campanian (83.6 - 72.1 Myr) to Thanetian (59.2-56 Myr). An important question to be addressed at both Sites U1575 and U1576 is whether the Tristan composition is present this far north in the >70 Ma part of the hotspot track. The basaltic rocks from Site U1577 will also provide further insight into the origin of the Valdivia Bank, where a continental fragment or microplate has been proposed. In the central Guyot Province, Site U1578 cored the lower flank of a guyot and penetrated ~302 m of igneous section intercalated with 10 distinct interbeds consisting of either pelagic or volcaniclastic sediments. The igneous rocks are alkalic basalts with eruption styles ranging from pillow flows to massive flows, the latter being up to 14.9 m thick. Changing eruptive styles and geochemistry, presence of sedimentary interbeds, and a magnetic reversal recorded within the section imply episodic volcanism over an extended period (>1Ma?). Abundant volcanic glass samples, in the form of pillow rims and at the margins of sheet and massive flows, and also fresh olivine were recovered at multiple locations within the cores. Although post-expedition studies have just begun, the recovery of well-preserved carbonate sediments and relatively fresh basalts, as well as abundant glass and fresh olivine in several recovered units (suitable for a variety of analytical applications), suggest that IODP Expedition 391 samples will provide important insights into the origin and evolution of the TGW hotspot track. Preliminary geochemical data on two alkalic glasses from Central Track site U1578 show that the uppermost unit has Gough type composition but lower (deeper) unit has a Central subtrack composition. The preliminary data suggest mixing between Gough and Tristan endmembers to generate the intermediate compositions.

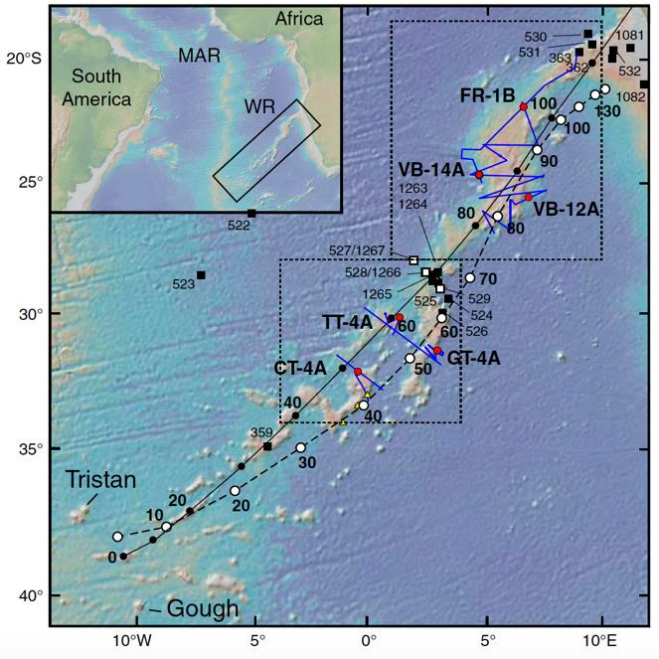

Figure 2: Showing the sites drilled in Exp. 391 (FR-1B = U1575; VB-14A = U1576; VB-12A = U1577; CT-4A = U1578) and planned for drilling in Exp. 397T (GT-4A and TT-4A).

IODP Expedition 397T, originally a simple transit from Cape Town to Lisbon, will provide ~7 days for drilling, giving Expedition 391 a second chance to core the remaining holes that could not be drilled due to Covid-related reduction of the originally scheduled working days. At the two preferred sites (GT-4a, TT-4a), the science party will attempt to drill ~100 m holes into the volcanic basement at both sites. If the expedition successfully reaches the volcanic basement, these sites in the Gough and the Tristan subtracks should provide us with the Gough and Tristan endmembers for the zoned portion of the TGW hotspot track.

IODP

Dynamics of the Pacific Antarctic Circumpolar Current over the past five million years (IODP Expedition 383 - DYNAPACC)

Frank Lamy[1]

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Our community's understanding of Earth's long-term climate evolution suffers a bias towards the Northern Hemisphere, where the majority of Plio-Pleistocene climate records have been developed. Although more recent efforts by the International Ocean Discovery Program (IODP) have sought to increase the number of long-term sedimentary records from the Southern Hemisphere (e.g. Expeditions 361, 374, 379, and 382), there remains an enormous gap in paleoclimate data from the South Pacific, representing the largest surface area and volume fraction of the Southern Ocean and therefore holding the largest capacity for carbon storage in the deep ocean.

Expedition 383, from May-July 2019, set out to fill this South Pacific data gap with the goal to improve our ability to understand global changes in ocean-atmosphere-ice sheet dynamics and carbon cycling during past climatic transitions.

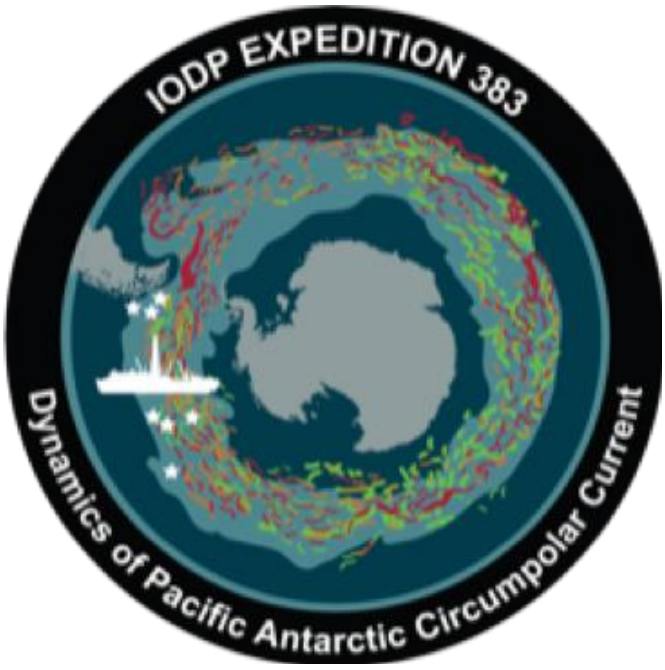

Figure 1: IODP Expedition 383 Logo

We present early results of a suite of complementary biological and geochemical tracers to reconstruct Plio-Pleistocene changes in nutrient cycling, carbon export, dust input and dynamics of frontal positions and the Antarctic Circumpolar Current using the newly recovered DYNAPACC sediment cores from the Subantarctic Pacific from IODP Expedition 383, with a focus on the intensification of Northern Hemisphere Glaciation, the Mid-Pleistocene Transition and Glacial/Interglacial cycles.

IODP

IODP Expedition 396 Report

Jack Longman[1]

1) ICBM, University of Oldenburg, Germany

Funded by the DFG, I was lucky to be selected as an Inorganic Geochemist on International Ocean Discovery Program (IODP) Expedition 396 "Mid-Norwegian Margin Magmatism and Paleoclimate Implications". As a palaeoclimatologist with a specific interest in the role of volcanism (and especially volcanic ash) in the carbon cycle and Earth system, this expedition was a great opportunity to recover sedimentary sequences documenting the impact of volcanic rifted margins on the climate. Specifically, the aims of this expedition were to drill sequences which cover the Paleocene-Eocene Thermal Maximum (PETM), and to investigate the potential role of the emplacement of the North Atlantic Igneous Province in this period of rapid climate warming 56 million years ago. To this end, the expedition was a tremendous success. The expedition took place between 6th august and 6th October 2021, and despite the challenges enforced by the COVID pandemic (leading to a smaller scientific party than usual), completed all objectives as stated at the outset. Following a week's quarantine in a hotel in Reykjavik, we transitioned to life aboard the r/v *JOIDES Resolution*, as participants in the first expedition since the beginning of the pandemic. Conditions onboard the JOIDES were a little different from normal, with masks required for the first two weeks, and with a little more breathing space, due to the reduced crew numbers. Aided by favourable weather conditions throughout (with only a handful of days of drilling lost to the weather), 20 boreholes were drilled at 10 sites in 5 locations across the Norwegian Margin. Of particular interest to me were the sedimentary sequences recovered from the Modgunn Arch and Mimir high localities, where PETM-age sediments from a crater fill (Modgunn) and in the Vøring transform margin depocenter (Mimir) were drilled.

Figure 1: Life in the Geochem lab – Image: Jack Longman

Recovery of these strata was generally good, with unprecedentedly extended PETM sequences (up to 60m of PETM-age sediment in Hole U1568A) recovered. It is possible some sections of sediment contain PETM-age sub-yearly laminations, with others appearing to cover the onset of the PETM itself. Relevant to my specific interests, extensive ash-containing sequences were recovered, which should allow for comparison with regional stratigraphies of early Eocene volcanism, and for investigation of the role of ashfall in carbon cycling at unprecedented resolution. In addition to PETM-age ash layers, numerous large Eocene and Miocene-age ashes were recovered from other locations. These large ash layers (up to 1m in thickness) will help aid in our understanding of local oceanographic (e.g. phytoplankton and carbon cycling) responses to major volcanic eruptive events. In addition, samples were recovered from sediments directly overlying NAIP basalts, and so investigation of the role these igneous rocks may have played in the Eocene Earth system may be carried out. With the help of recently-confirmed follow-on funding from the DFG, extensive geochemical analyses will be carried out on the samples recovered. These analyses should help to answer a wide range of questions relating to the role of the NAIP, and especially ashfall events, in the climate of the early Eocene North Atlantic.

Figure 2: Waiting for cores in the age of COVID – Image: Jack Longman

IODP

IODP Expedition 378 "South Pacific Paleogene Climate"

Ursula Röhl[1], Deborah Thomas[2], Laurel Childress[3] & the Exp. 378 Science Team

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2) College of Geosciences, Texas A&M University, USA
3) International Ocean Discovery Program, Texas A&M University, USA

IODP Expedition 378 was designed to recover the first comprehensive set of Paleogene sedimentary sections from a transect of sites strategically positioned in the South Pacific to reconstruct key changes in oceanic and atmospheric circulation. These sites would have provided an unparalleled opportunity to add crucial new data and geographic coverage to existing reconstructions of Paleogene climate. In addition to the ~15 month postponement of Expedition 378 and subsequent port changes resulting in a reduction of the number of primary sites, testing and evaluation of the R/V JOIDES Resolution derrick in the weeks preceding the expedition determined that it would not support deployment of drill strings in excess of 2 km. Because of this determination, only 1 of the originally approved 7 primary sites was drilled.

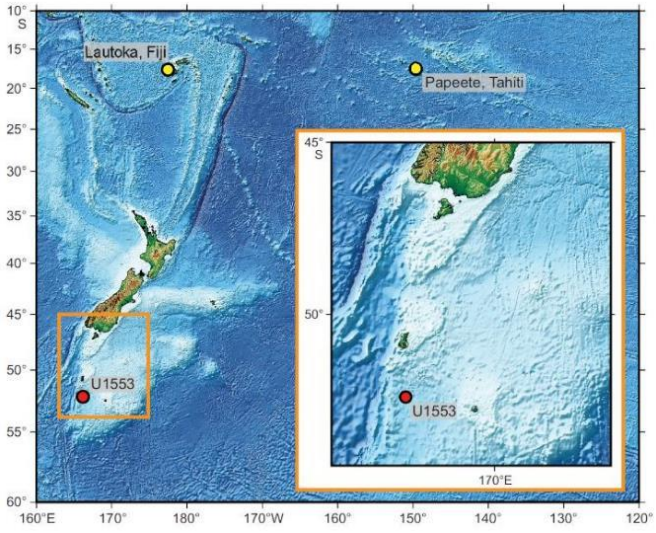

Figure 1: Overview map.

Expedition 378 recovered the first continuously cored, multiple-hole Paleogene sedimentary section from the southern Campbell Plateau at Site U1553. This high–southern latitude site builds on the legacy of Deep Sea Drilling Project (DSDP) Site 277, a single, partially spot cored hole, providing

a unique opportunity to refine and augment existing reconstructions of the past ~66 My of climate history. This also includes the discovery of a new siliciclastic unit that had never been drilled before.

As the world's largest ocean, the Pacific Ocean is intricately linked to major changes in the global climate system. Previous drilling in the low-latitude Pacific Ocean during Ocean Drilling Program (ODP) Legs 138 and 199 and Integrated Ocean Drilling Program Expeditions 320 and 321 provided new insights into climate and carbon system dynamics, productivity changes across the zone of divergence, time-dependent calcium carbonate dissolution, bio- and magnetostratigraphy, the location of the Intertropical Convergence Zone, and evolutionary patterns for times of climatic change and upheaval. Expedition 378 in the South Pacific Ocean uniquely complements this work with a high-latitude perspective, especially because appropriate high-latitude records are unobtainable in the Northern Hemisphere of the Pacific Ocean.

Site U1553 and the entire corpus of shore-based investigations will significantly contribute to the challenges of the "Climate and Ocean Change: Reading the Past, Informing the Future" theme of the IODP Science Plan (How does Earth's climate system respond to elevated levels of atmospheric CO2? How resilient is the ocean to chemical perturbations?). Furthermore, Expedition 378 will provide material from the South Pacific Ocean in an area critical for high-latitude climate reconstructions spanning the Paleocene to late Oligocene.

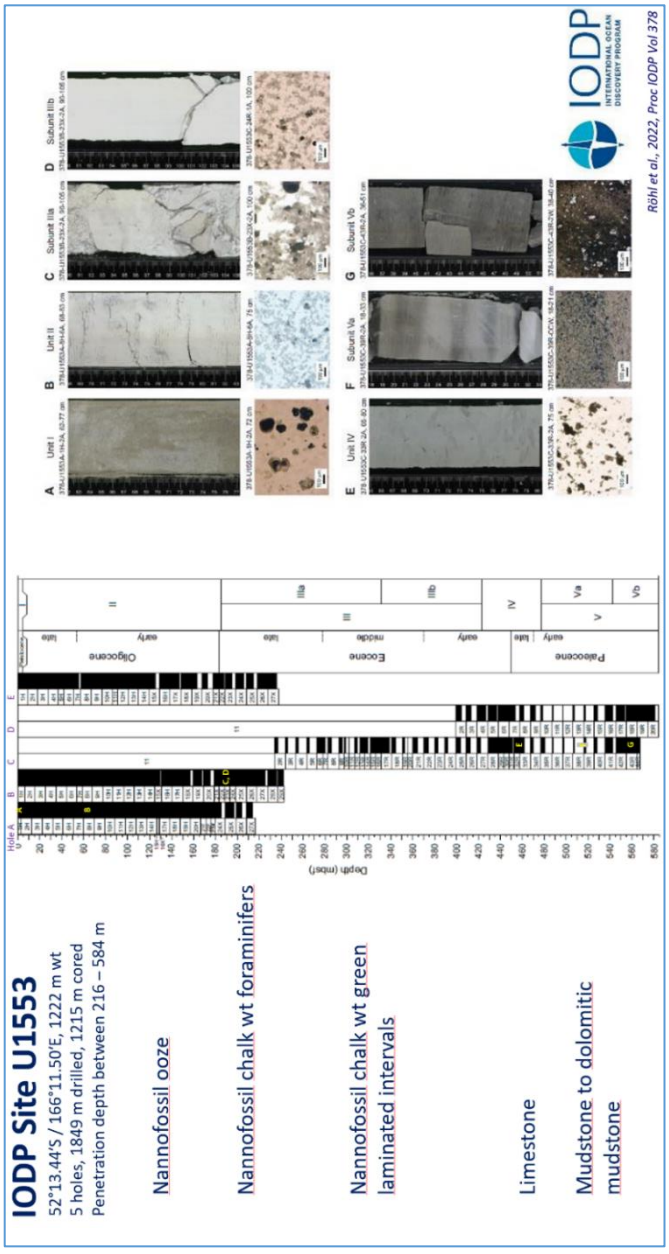

Figure 2: IODP Site U1553.

References:

Thomas, D.J., Röhl, U., Childress, L.B., and the Expedition 378 Scientists, 2020. Expedition 378 Preliminary Report: South Pacific Paleogene Climate. International Ocean Discovery Program. https://doi.org/10.14379/iodp.pr.378.2020

Röhl, U, Thomas, DJ, Childress, LB and Expedition 378 Scientists (2022) South Pacific Paleogene Climate. Proceedings of the International Ocean Discovery Program, 378. College Station, TX (International Ocean Discovery Program). https://doi:10.14379/iodp.proc.378.2022

IODP

IODP Expeditions 390 and 393: South Atlantic Transect

Claire M. Routledge[1], Leonardo Tamborrino[2], Elmar Albers[3] & the IODP Expedition 390/393 Scientists

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2 MARUM – Center for Marine Environmental Research, University of Bremen, Germany
3 Department of Geosciences, University of Bremen, Germany

The "South Atlantic Transect" (SAT) was a multidisciplinary ocean drilling project that comprised two expeditions (390 and 393) carried out on D/V JOIDES Resolution. Aimed at recovering basaltic crust of aging oceanic lithosphere and the overlying sedimentary sequences, six sites were drilled along a slow to intermediate spreading Mid-Atlantic Ridge crustal flow line at ~31°S (Fig. 1). The primary scientific objectives of the SAT were (1) to quantify the timing, duration, and extent of hydrothermal fluid–rock exchange on the flank of a mid-ocean ridge setting (Fig. 2), (2) to investigate sediment- and basement-hosted microbial community variations with substrate composition and age (Fig. 2), and (3) to investigate the responses of Atlantic Ocean circulation patterns and the Earth's climate system to rapid climate changes, for instance during the Cenozoic (Fig. 3). SAT revisited an area previously cored during Deep See Drilling Project Leg 3 aboard D/V Glomar Challenger in Dec 1968–Jan 1969, a significant expedition designed to verify the theories of seafloor spreading and plate tectonics.

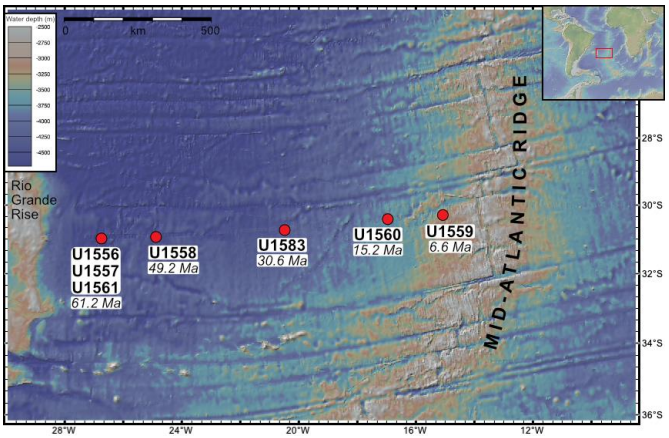

Figure 1: Sites drilled in aging oceanic crust during Expeditions 390 and 394: South Atlantic Transect.

Expeditions 390 and 393 took place from 7 Apr–7 Jun and 7 Jun–7 Aug 2022, respectively, both starting and ending in Cape Town, South Africa. In addition, two expeditions (390C, Oct–Dec 2020, and 395E, Apr–Jun 2021) were implemented in response to the COVID-19 pandemic, during which a single sedimentary hole at each site was cored to the sediment–basement interface with casings and reentry systems installed, enabling operational time to be maximized during Expeditions 390 and 393. During Expeditions 390C and 395E, all sediment cores were split, imaged, and had ship-based measurements taken at the time; the cores were described and biostratigraphic samples were taken and analyzed during transit on Expeditions 390 and 393.

Across the four SAT expeditions, ocean crust of ~7, 15, 31, 49, and 61 Myr in age was cored using advanced piston corer and extended core barrel assemblies for sediments and a rotary core barrel unit for basement. Twenty

sediment holes were cored at seven sites, resulting in 2,112 m cored and 1,854 m recovered sediment (87.8%). A single basement hole was cored at six of the sites with 913 m cored and a recovery of 452 m (49.5%). Wireline logging runs were conducted in four holes using a combination of a triple combination ("triple combo"), a Formation MicroScanner, and an Ultrasonic Borehole Imager.

Sediments were cored to the sediment-basement interface at 6.6 Myr old Site U1559 (to 66.2 m below seafloor [mbsf] in 3,055–3,058 m water depth), at 15.2 Myr old Site U1560 (to 129 mbsf in 3,724 m water depth), at 30.6 Myr old Site U1583 (to 105.2 mbsf in 4,210–4,215 m water depth), at 49.2 Myr old Site U1558 (to 176 mbsf in 4,334–4,337 m water depth), and at 61.2 Myr old Sites U1556, U1557, and U1561 (to 564.8 mbsf in 4,924–5,012 m water depth). The sediment cored across the SAT provides an ideal opportunity to investigate the paleoceanographic evolution of the South Atlantic Gyre throughout the Cenozoic. This includes changes in the thermohaline circulation, especially regarding the initiation and variability of the Antarctic Bottom Water and North Atlantic Deep Water water masses which play a key role in the Atlantic overturning circulation, and which heavily influence Earth's climate history. Across the SAT, an almost complete sedimentary record dating from the late Paleocene through Recent was recovered and records all major paleoclimatic events in the Cenozoic (Fig. 3), and the presence and impact of several unconformities/condensed intervals was mitigated by overlapping successions at different sites.

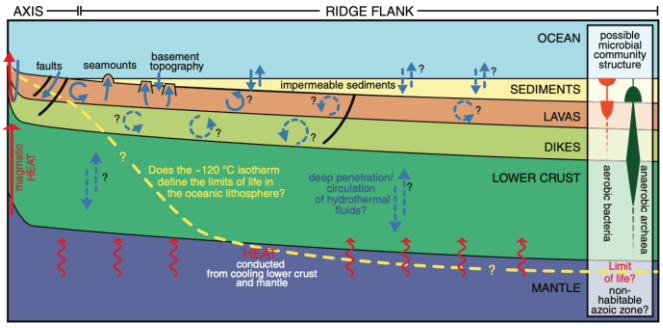

Figure 2: Schematic architecture of a mid-ocean ridge flank. With crustal age, the intensity and style of hydrothermal alteration change and the 120°C isotherm, defining the limits of life, is thought to subside to deeper levels. From Coggon et al. (2020), mainly after Coggon & Teagle (2011).

The sedimentological record across the SAT sites, characterized by calcareous nannofossil ooze/chalk and intervals of siliciclastic material, reflects the spatio-temporal variability of the lysocline and calcite compensation depth (CCD). The presence and abundance of calcareous microfossils across the SAT was strongly influenced by the sediment composition, with clays often barren of fossils, or comprising poorly preserved and depauperate assemblages, suggesting the site was likely situated below the CCD. In the carbonate-rich sections, calcareous fossils were often diverse and well preserved, and should prove suitable for post-expedition isotope studies.

Basement was cored at Sites U1559 (to 42.9 m into basement), U1560 (to 192.2 m), U1583 (to 129.8 m), U1558 (to 203.4 m), U1556 (to 118.1 m), and U1557 (to 355.2 m) and visually described for igneous characteristics and alteration features. The recovered rocks are basalt pillow lavas and sheet flows. They contain varying amounts of plagioclase, olivine, and clinopyroxene phenocrysts in mostly cryptocrystalline to fine-grained but in cases medium-grained groundmass. The basalts show different degrees of mostly low-temperature hydrothermal alteration, ranging from weakly altered background over moderately altered early-stage dark gray to light brownish halos following narrow fractures to strongly altered and presumably highly oxidized brown–orange domains associated with chilled margins or fractures within the flows. Whereas basalts at the younger sites are characterized by weak to moderate alteration, an increase towards considerably higher alteration degrees was observed across the SAT. Hydrothermal precipitates, mainly clays, carbonate, and zeolites, filling vesicles, vugs, and veins were found throughout all cores. Veins were, in addition, commonly filled by metamorphosed carbonaceous sediments. With up to seven occurrences per meter, our recovery contained high densities of both fresh and variably altered basaltic glass. The cores also comprised breccias consisting of variably altered clasts of basalt and/or basaltic glass and matrices of metamorphosed carbonaceous sediment, cemented by carbonates and/or zeolites.

Across the SAT, standard physical properties were recorded on sediment and basement cores as well as on discrete samples. High-resolution 3D photographs were taken for basement core pieces of adequate size and shape using a DMT scanner. Paleomagnetic investigations included natural remanent magnetization measurements and alternating field and thermal demagnetization on cores and discrete samples of both sediment and basement.

Geochemical analyses included headspace analysis of hydrocarbon gases, in situ porewater oxygen measurements, interstitial water chemistry, loss on ignition, inorganic and total carbon, and elemental compositions of sediment and basement samples using ICP-AES; during Exp. 390, sulfide concentrations in interstitial water were also determined, and during Exp. 393, with a total of ~1,200 analyses, a pXRF was used to obtain a high-resolution elemental composition record of basement recovery.

To trace subseafloor life, including microbial activity in the sediments, the sediment–basement interface, and in the basement, representative whole-round samples were collected for microbiological analysis. Samples were prepared for DNA and RNA analysis, single cell genomics, lipid analysis, cell and viral counting, and viral activity measurements, most of which will be shore-based work. Quantification of a contamination tracer suggested minimal contamination by drilling fluids in the interior of whole-round samples and hence promising post-cruise work.

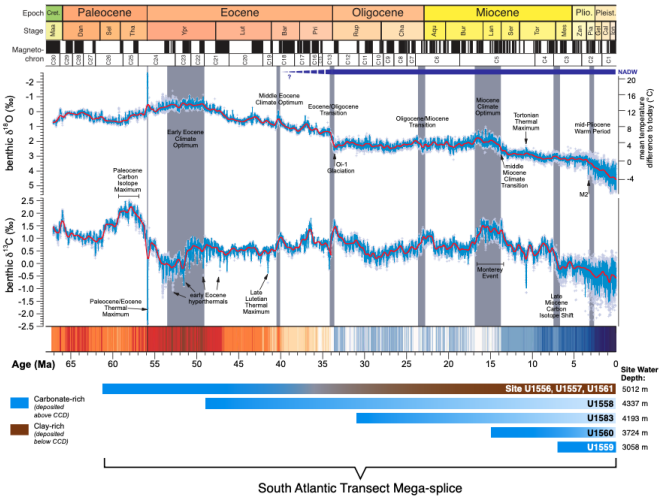

Figure 3: Overview of Cenozoic climate evolution (Coggon et al., 2022). Compilation of deep-sea benthic isotope records (Westerhold et al., 2020) with major climatic events (grey). SAT sites shown with age and modern water depth, with colors indicating carbonate-rich sediments (blue), deposited when the site was closer to the ridge crest and above the CCD, transitioning to carbonate-poor sediments (brown), as the site subsided below the CCD.

Overall, during Expeditions 390 and 393, we were able to fill critical gaps in our sampling of intact *in situ* ocean crust as well as recovering the overlying sedimentary sequences from the relatively understudied western South Atlantic. The main post-cruise research plans of the German participants focus on: drawing conclusions about the evolution and scale of paleoclimatic and paleoceanographic changes recorded in plankton through the Paleogene and Neogene (CR, LT), and on changes in alteration degree, redox conditions, and associated energy availability for microbial activity in the aging basement (EA).

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IODP

Initial results of IODP Expedition 392: Agulhas Plateau Cretaceous Climate

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3) International Ocean Discovery Program, Texas A&M University

International Ocean Discovery Program Expedition 392 drilled three sites on the Agulhas Plateau and one site in the Transkei Basin in the Southwest Indian Ocean in Ferb-March 2022 (Fig. 1).

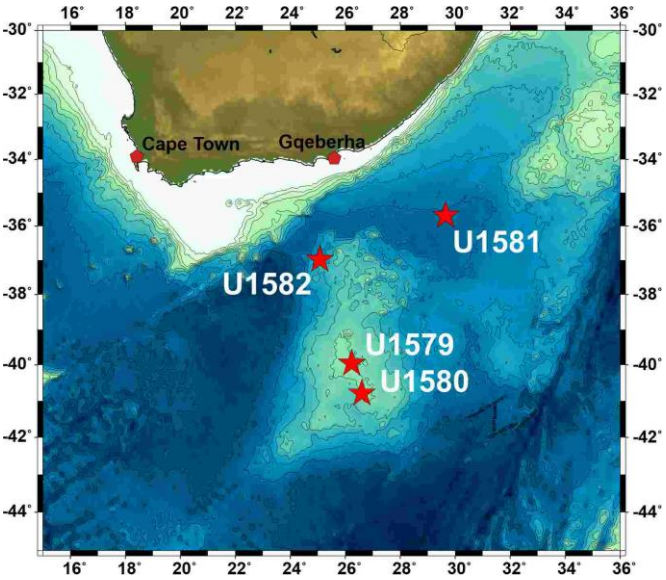

Figure 1: Agulhas Plateau and Transkei Basin.

This region was positioned at paleolatitudes of ~53°–61°S during the Late Cretaceous (van Hinsbergen et al., 2015), within a new and evolving oceanic gateway between the South Atlantic, Southern Ocean, and southern Indian Ocean basins. Sedimentary and basement sequences were successfully recovered from the Agulhas Plateau sites U1579, U1580, and U1582, and a thick sedimentary sequence was recovered in the Transkei Basin at Site U1581 (Fig. 2).

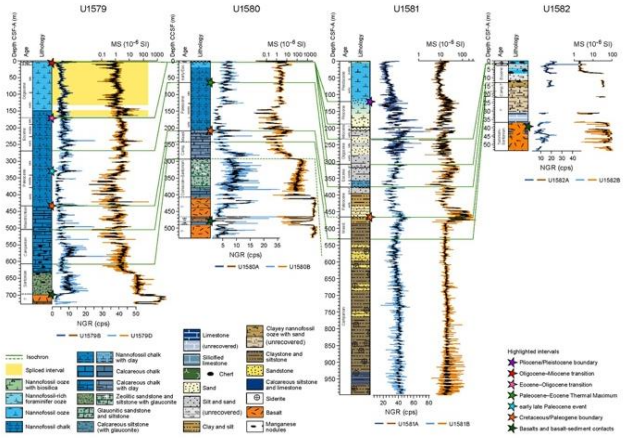

Figure 2: Lithologic summary with shipboard natural gamma ray (NGR) and magnetic susceptibility (MS) records, Sites U1579-U1582. cps = counts per second. From Uenzelmann-Neben et al. (2022).

Drillcores from these four sites provide a wealth of new data to (1) determine the nature, origin, and bathymetric evolution of the Agulhas Plateau; (2) significantly advance the understanding of how Cretaceous temperatures, ocean circulation, and sedimentation patterns evolved as CO_2 levels rose and fell and the breakup of Gondwana progressed; (3) document long- and short-term paleoceanographic variability through the Late Cretaceous and Paleogene; and (4) investigate geochemical interactions between igneous rocks, sediments, and pore waters through the life cycle of the Agulhas Plateau large igneous province (LIP).

Importantly, postcruise analysis of Expedition 392 drill cores will allow testing of competing hypotheses concerning Agulhas Plateau LIP formation and the role of deep ocean circulation changes through southern gateways in influencing Late Cretaceous–Paleogene climate evolution.

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Kurzfassungen - Abstracts

IODP

Late Eocene to Oligocene carbon cycle stories: Expedition 378

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Atmospheric carbon dioxide concentration (CO_2) is a key driver of climate change, from recent to geologic timescales[1], but the ways in which atmospheric CO_2 modifies climate and sea-level remain uncertain[2], even though sea-level change is the most significant and long-lasting consequence of anthropogenic CO_2 climate change[3]. Therefore, we aim to identify the relationship -and its underlying mechanism- between CO_2, climate and sea-level at key periods in the geologic past with large amplitude changes in sea-level and CO_2 to improve our understanding of the sensitivity of large continental ice sheets, such as in Antarctica, in a high CO_2 world. Here, we will present our recently started DFG-IODP project on the late Eocene and Oligocene. We will also discuss ongoing work exploring seawater pH and atmospheric CO_2 reconstructions using boron isotopes in planktonic foraminifera, such as from material collected during Expedition 378 [4].

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IODP

Microbial life in an ultra-deep sulfate-methane transition zone on the Antarctic continental margin

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Marine sediments are considered to contain microbial biomass that equals the stock of living biomass in the overlying ocean waters. Comprehensive knowledge on the spatiotemporal distribution and abundance of microbial life in marine sediments, however, is still sparse. A region particularly understudied in this respect is the Antarctic continental margin, in which the deep biosphere is largely *terra incognita*. A 794 m-long sediment sequence (Site U1532), recovered during IODP Expedition 3710) "Amundsen Sea West Antarctic Ice Sheet History" from the Resolution Drift (western Antarctica; water depth of 3962 m) provides, for the first time, the unique opportunity to study the composition and abundance of the deep biosphere in polar regions of the Southern Hemisphere. Porewater profiles of sulfate and methane concentrations indicate that the sulfate-methane transition zone (SMTZ) at Site U1532 is located at a depth of ~670 mbsf, making it one of the deepest SMTZ ever encountered. Stable carbon isotope measurements attest to the biological origin of the methane and provide direct evidence for an active deep-dwelling microbial community. Cell abundances decline with depth by three orders of magnitude but substantially increase again within the SMTZ. Complementary intact polar lipid analysis indicates that this change in cell abundance is associated with a shift in the microbial community to predominantly methanogens throughout and below the SMTZ. Our data thus provides first insights into the microbial diversity and abundance of the deep biosphere in the yet largely unstudied marine sediments surrounding Antarctica. They also suggests that global cell estimates in marine sediments may be overestimated and careful revision is needed.

IODP

Marine tephra layers in the Indian Ocean and their volcanological implications: a story of not just Toba

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Three IODP Expeditions (353, 354, and 362) as well as seven ODP and DSDP Legs (183, 121, 120, 119, 116, 115, and 22) drilled 23 sites in the Indian. The recovered sediments contain marine tephra layers that reveal the volcanic history of the adjacent volcanic arcs and oceanic islands

The most prominent example of this region is probably Toba volcano, which is the host of the 75 ka Toba eruption also known as the Young Toba Tuff (YTT) and three older eruptions, the Middle (MTT) and Older Toba Tuff (OTT) as well as Haranggaol Dacite Tuff (HDT). However, although the Toba eruptions are widely distributed in the Indian Ocean and can be found in 14 of the investigated sites, there is more to discover besides Toba and more to learn from Toba.

We geochemically analyzed 310 marine tephra samples for their glass composition and performed more than 4300 major element analyses by electron microprobe, and nearly 1000 trace element analyses by Laser-Ablation ICP-MS. Resulting from these analyses and combined with petrographically observations we classified 235 of these samples as tephra layers that predominately contain pyroclastic material (in the 63–125 micron fraction).

A broad range from basaltic to rhyolitic as well as trachytic compositions exist in the investigated tephra layers. In a first step they can be grouped into arc-derived and ocean island derived origin, but also a more specific correlation is often possible, as for example the multiple correlations to four known and several older, so far unknown, Toba-derived eruptions, as well as several eruptions from other Sumatran sources.

Finally, we were able to use the distribution and geochemical correlations between marine tephra layers, but also with terrestrial data to build a tephrostratigraphic framework, and we were able to estimate tephra volumes and magma masses for the younger Northern Sumatran eruptions.

ICDP

Seismic crosshole investigations at the Tannwald drillsite (ICDP DOVE project)

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The ICDP Tannwald drilling project consists of three boreholes, all of which reach the base of the Quaternary overdeepened basin between 153 and 158 m depth (Anselmetti et al., 2022; Tanner et al., 2022). The boreholes are arranged as an isosceles triangle with short edges of 28 m in N-S and W-E direction. Based on the geology, we hypothesize that the sediments of the Tannwald Basin could show seismic anisotropy which provides information on the sedimentation processes. However, traditional surface seismic methods did not confirm this effect on wave propagation reliably due to the low-velocity weathering layer and the too low frequencies. Furthermore, the predominantly vertical travel paths that are used in surface methods together with local heterogeneities impair AVO/AVA methods that make use of horizontal travel paths, prohibiting seismic anisotropy investigation. These

obstacles can be overcome by means of the crosshole setup.

During two surveys in spring of 2022, P-waves were excited using a borehole sparker and recorded by a 24-station hydrophone string. A SH- and a SV-source produced polarized S-waves in borehole B that were registered by a 8-station three-component geophone string in borehole C. Additionally, we employed three-component surface geophones in profile between boreholes A and B as well as B and C. Further geophones were set up in a circular fashion around borehole B for an inverse walk-around VSP. The data set comprises over 360 shot points and amounts to about 120 GB.

We will investigate seismic anisotropy by means of a polarization analysis and the inverse walk-around VSP will provide information about azimuthal anisotropy. Subsurface models of the geology between the three boreholes will be obtained by traveltime tomography and refined by full-waveform inversion.

First data analysis shows waveforms with a high frequency content, which promises subsurface models with an increased resolution compared to surface seismic methods. Lower frequencies, which are important for the proper convergence of a full-waveform inversion, however, are absent and therefore present a big challenge for the inversion process.

Figure 1: We orient the SH-source manually using the torsionally stiff hose and secure it at its position by clamping the hose between the two boards of a workbench.

ICDP

The 8.2 ka event in the Dead Sea: tracking a high-latitude disturbance in the Mediterranean

Cecile Blanchet[1], Assil Nwaigy[2], Hana Jurikova[3], Rik Tjallingii[1], Michael Henehan[1], Markus Schwab[1], Achim Brauer[1]

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The last deglaciation is an ideal time interval to investigate the effect of climatic and oceanic disturbances occurring at high latitude on the hydrological regimes of the Mediterranean Sea. In particular, a series of disruptions of the Atlantic Meridional Oceanic Circulation (AMOC) has punctuated the transition from glacial to interglacial conditions, with the so-called 8.2 ka event being the youngest one. After the publication of recent results showing the existence of instable climatic conditions in the Dead Sea during the Younger Dryas (Müller et al., 2022), we examine here the environmental record during the 8.2 ka event to illuminate the effects of the background climate (colder to warmer) on hydrological distrubances linked to AMOC disruptions. We performed a coupled limnological and geochemical analysis of sediments deposited in the deeper part of the Dead Sea (IDCP site 5017A), which showed the occurrence of repeated mass wasting deposits related to intense erosive activity in the watershed of the Dead Sea. An identified hiatus in outcrop sequences from western lake shores suggests a drop in lake level at that time (Migowski et al., 2006). Ongoing analyses of sediment provenance and classification of mass wasting events will provide additional insights on the precise processes operating at that time, as well as the climatic regimes associated.

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IODP

Short-term waxing and waning of Antarctic ice sheets during the late Oligocene – evidence from benthic foraminiferal geochemistry and detrital Nd isotopes

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Sandwiched between the early Paleogene greenhouse and Neogene icehouse climates, the Oligocene epoch (33.9–23.03 Ma) represents what is arguably the most important transitional phase of Cenozoic climate evolution, with the first major expansion of Antarctic ice sheets (AIS). Temporally highly resolved paleoclimatic and paleoceanographic proxy records for the Oligocene therefore are a prerequisite for obtaining deeper insight into the fundamental mechanisms and processes involved in the waxing and waning of continental ice sheets. Whereas the long-term evolution of Oligocene glaciations is rather well known, current knowledge about short-term (i.e., orbital to suborbital scale) ice-sheet dynamics is still very limited and a matter of ongoing debate. Therefore, the focus of this project is to elucidate short-term ice-sheet dynamics during the Oligocene based on proxy data from ODP Site 689 (Maud Rise, Weddell Sea, Southern Ocean). Stable oxygen isotope measurements of benthic foraminifera have been used to establish a high-resolution age model for the studied interval of Site 689 that also allows correlation to recently established chronologies of North Atlantic IODP Site U1406. Mg/Ca-based bottom-water temperature (BWT) reconstructions have been established on the same samples to allow the $\delta^{18}O$ of seawater ($\delta^{18}O_{sw}$; a proxy for sea-level/ice-volume) to be calculated. In addition, neodymium

(Nd) isotope signatures of the detrital sediment fraction have been measured to characterize weathering and source-rock changes.

The Site 689 $\delta^{18}O_{sw}$ record displays values ranging between -0.6 to ~0.2 ‰ with distinct changes between glacial/interglacial conditions. Our new reconstructions infer a highly dynamic AIS in the late Oligocene that was characterized by glacial conditions with an AIS volume comparable or even slightly larger than today ($\delta^{18}O_{sw}$ values of ~0.2 ‰) and interglacial conditions that experienced a much smaller continental ice sheet on Antarctica ($\delta^{18}O_{sw}$ values of ~-0.5 ‰). It becomes evident that BWTs at Site 689 document only a minor contribution of bottom-water cooling to the inferred glacials and therefore only a weak correlation with the $\delta^{18}O_{sw}$ reconstructions. We suggest that this is due to only minor changes in BWT over time in the Southern Ocean whereas the late Oligocene cryosphere was much more responsive to climatic forcing on orbital time scales.

Our detrital Nd isotope record from Site 689 shows distinct fluctuations between -9 to -12 εNd units that vary in concert with the Site 689 $\delta^{18}O_{sw}$ record. More specifically, intervals of higher $\delta^{18}O_{sw}$ values (glacials) are characterized by less radiogenic detrital Nd-isotope signatures whereas intervals of lower $\delta^{18}O_{sw}$ values (interglacials) show more radiogenic signatures. This co-variation of an indirect ice-sheet marker on the one hand, and a sediment provenance tracer on the other strongly supports the above-mentioned interpretation of a highly dynamic AIS and therefore substantial variations in Antarctic ice cover. We conclude that these variations reflect the variable sedimentary source area of glacial erosion and therefore the provenance of weathering products transported from the Antarctic continent into the Southern Ocean in concert with the reconstructed orbitally-paced waning and waxing of the AIS.

ICDP

Improving the characterization of overdeepened Alpine valleys by combining seismic reflection imaging and waveform inversion

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What types of small-scale Quaternary structures are hidden within the sedimentary succession of the overdeepened Alpine valleys? How heterogeneous is the bedrock topography of overdeepened valleys? Why are upright standing trees distributed all across the bottom of Lake Altaussee? State-of-the-art seismic methods struggle to answer these and other open questions that arose within the ICDP-project Drilling Overdeepened Alpine Valleys (DOVE). In particular at the sites Schäftlarn (Germany) and Bad Aussee (Austria), the limitations in resolution and accuracy of parameter determination hamper answering these questions. Therefore, we intend to improve the characterization of the sedimentary succession of overdeepened Alpine valleys by combining high-resolution seismic reflection imaging (HRSR) and full waveform inversion (FWI). Our concept comprises a methodological development of (1) an interplay of both methodologies that will constrain the FWI with information from the HRSR, and enables sophisticated processing with velocities from FWI. (2) A workflow will overcome prerequisites of FWI, i.e. the low frequency content that is usually excited by explosive sources, which are subject to legal regulations. It will enable the interplay to other sites, where only vibratory data exist. Finally, we will (3) test the applicability of the concept at other DOVE sites and ensure a comparable characterization of the DOVE sites. Within the project, we will acquire P-wave seismic data using vibratory and explosive sources as well as S-wave seismic data using vibratory sources at sites Schäftlarn and Bad Aussee. State-of-the-art HRSR processing of the vibratory data and FWI of the explosive data will give the first insight into the sedimentary interior of the two overdeepened valleys, where no high-resolution seismic data exist so far. At these structures, we will develop and realize our concept. Partners within the project are the Bavarian and Austrian Geological Surveys as well as the University of Natural Resources and Live Sciences Vienna.

ICDP

Seismic site characterization around the COSC-2 drillhole (Järpen, Sweden)

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The ICDP funded project COSC (Collisional Orogeny in the Scandinavian Caledonides) is investigating mountain building processes with the help of two ~2.5 km deep fully cored boreholes in Central Sweden (Åre and Järpen/Mörsil). While borehole COSC-1, drilled in 2014, studied the emplacement of the high-grade metamorphic allochthons, borehole COSC-2, drilled in 2020, focuses on defining the character and age of deformation of the underlying greenschist facies thrust-sheets, the main Caledonian décollement and the Precambrian basement.

During a three-week survey in September and October 2021, we performed an extended walkaway VSP survey at the COSC-2 drill site. The objective of it was to derive a high-resolution 3D image of the subsurface in the direct vicinity of the borehole and to assist the geological interpretation by determining the origin of the basement reflections, the nature of the main décollement, and the degree of basement thrusting. The main survey component consisted of two 2D surface seismic lines approximately perpendicular to each other and centered around the COSC-2 drill site (see Figure 1). Single (1C) and three-component (3C) geophones were deployed along the lines at intervals between 5-100 m. A 32 t Vibroseis source operated along both lines with source point distances between ~100-500 m. One of the 2D lines crossed a nearby lake, where ocean bottom seismometers (OBS) were deployed and an airgun source was used to cover this ~1.5 km wide part of the profile. Along the entire borehole down to a depth of 2.26 km, a 3C geophone chain recorded the seismic wavefield from all source points with a geophone spacing of 10 m as well as from one single source point close to the borehole with a geophone spacing of 2 m.

The obtained surface seismic and VSP data set exhibits an exceptionally good quality and shows many pronounced and clear reflections in the raw gathers. They are observed even at the largest source-receiver offsets (~11 km) and are visible at two-way-traveltimes down to 3-4 s, corresponding to structures at a depth of approximately 11 km. First results of the ongoing data processing and analysis will be presented, including a P-wave velocity model obtained from first arrival traveltime tomography as well as interpretations of its anisotropic characteristics related to the geological structures in the area.

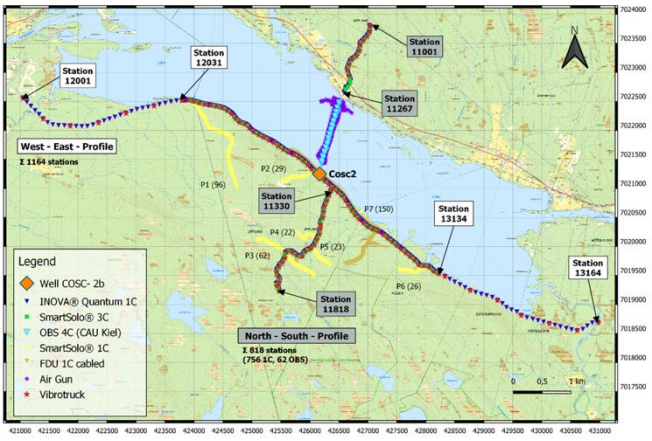

Figure 1: Survey layout around the COSC-2 borehole.

ICDP

Oxide nanolites formation and subsequent viscosity changes in Krafla magma

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Magmas ascending to shallow levels in the Earth's crust are subjected to decompression and cooling. Due to decompression, magmas lose volatiles that, added to cooling, increase melt viscosity and change the magma *liquidus*, processes that lead to nucleation and growth of crystals. Both viscosity and crystal content are critical properties controlling the behaviour of erupting volcanoes. The bulk viscosity of a magma is largely controlled by the viscosity of its melt phase and its suspended (or dispersed) crystal load, for which micolites and phenocrysts are normally considered. Yet the effects of nanolites (nanometre-sized magmatic crystals) formation on magma bulk viscosity due to chemical changes in the melt phase and the crystal load that nanolites provide remain highly unexplored.

Past eruptions at Krafla volcano, Iceland, have produced rhyolitic magma from which nanolites can form. Previous experimental work shows that Krafla rhyolitic magma has the composition (high-Fe) and capability to form nanolites in a short scale of time when the magma is subjected to suitable crystallisation conditions. Furthermore, nanolites formed before degassing events in Krafla rhyolitic magma can drive accelerated volatile exsolution and hence fast vesiculation-driven magma expansion. These processes have the potential to shift an initially quiescent effusive eruption into a violent explosive behaviour in the event of an eruption.

Here we conducted highly controlled magma cooling experiments at oxidising conditions and later viscosity measurements on an iron-bearing rhyolitic magma, in order to explore the effects of nanolites nucleation and growth on both melt and bulk viscosities. During cooling from *superliquidus* conditions, oxide nanolites nucleated in the rhyolitic melt. Both thermal and viscosity analyses show that nucleated oxide nanolites can rapidly grow when magma is re-heated. These analyses also show that the effect of nanolite growth on bulk magma viscosity can be significant, and it is mainly due to iron depletion of the melt phase. Depending on the dynamics of magma degassing and ascent, the viscosity increase due to nanolites crystallisation may hold the potential to shift a magma into explosive behaviour.

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Estimating Earthquake Source Parameters in the Sea of Marmara

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Earthquake source parameters are of great significance for both understanding earthquake physics and evaluating seismic hazard. One of the fundamental source parameters, stress drop, plays a key role in impacting the frequency content of ground motion, which is of significance for the seismic hazard assessment, especially near the densely populated region like Istanbul. Utilizing the ground and borehole seismic recordings, we estimate the earthquake source parameters for seismicity in the Sea of Marmara. Using a spectra fitting approach, we constrain the quality factor, corner frequency, and seismic moment, and calculate the earthquake stress drop using a Brune source model for 1751 earthquakes in the Marmara region during 2006-2020. Most of the stress drop range from 1 to 10 MPa, with a median value of 2.6 MPa. We observe spatial variations of stress drop values along the Main Marmara Fault. In the creeping section, the stress drop values of 56 repeating earthquakes are derived showing similar values compared to the surrounding regular earthquakes. Constraining earthquake source parameters would contribute to our knowledge of source scaling and earthquake characterization, and provide information on seismic hazard.

IODP

IODP APL 692: Linking sediment deposition during glacial cycles and methane hydrate occurrence

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Methane hydrate is an ice-like solid composed of CH_4 and H_2O found within sediments on continental slopes worldwide. Most accumulations of hydrate are likely low in concentration, yet these summed accumulations are estimated to contain 5-30% of global mobile carbon. Unfortunately, however, our ability to locate and quantify the amount of hydrate below the seafloor is poor.

In IODP Ancillary Project Letter (APL) 691, which has passed all review panels and is awaiting scheduling, we propose a novel way to identify low concentrations of methane hydrate. We hypothesize that increased organic carbon deposited during glacial sea level lowstands could explain hydrate accumulations in laterally extensive marine mud units worldwide. If true, this may provide a new approach to identifying and quantifying low-concentration hydrate below the seafloor.

The eustatic sea level decrease during glaciations increases the concentration and preservation of particulate organic carbon, which may be caused by higher sediment supply, shelf bypass and/or higher marine biological productivity. Over time, the labile fraction of organic carbon in marine mud is consumed by microbes and eventually causes the reactions that generate methane. As more methane is generated, the dissolved methane concentration in the pore water eventually reaches solubility and methane hydrate forms within marine mud. In IODP APL 961, we propose to test this hypothesis in the hydrate-bearing Mendenhall marine mud unit located in the Terrebonne minibasin on the northern Gulf of Mexico continental slope. At Terrebonne, we are able to leverage several existing datasets, including high resolution 2D seismic and two logging-while-drilling (LWD) scientific boreholes which measure the laterally extensive Mendenhall Unit. Modeling suggests this unit could be related to the Wisconsin glacial lowstand, ~75-11 ka.

At three Terrebonne sites, we propose to core with the advanced piston corer to 152 mbsf to determine the concentration of labile and refractory organic carbon, sediment age, glacial cycles and sedimentation rates as well as characterize the pore water geochemistry, gas geochemistry and the microbial communities in and around the Mendenhall Unit. To identify the occurrence of gas hydrate, we will use existing LWD data, infrared camera images of core and pore water geochemistry. We will integrate all of these datasets to test the hypothesis that the increased preservation of particulate organic carbon during glacial sea level lowstands affects the occurrence of methane hydrate in marine muds.

IODP

Middle Eocene to the early Miocene absolute paleolatitude of northern Zealandia determined from the sedimentary record of IODP Exp. 371 (Tasman Sea)

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Northern Zealandia is a continent submerged for more than 90% under the water of the southwest Pacific Ocean and separated from Australia by the Tasman Sea ocean basin. Its absolute position since its drift form Australia in the Cretaceous is determined by means of global absolute plate motion models, as local paleomagnetic constraints are completely missing. We present new absolute paleolatitudes for northern Zealandia using paleomagnetic data from sediments drilled in International Ocean Discovery Program Sites U1507 and U1511 (Expedition 371, Sutherland et al., 2019; Dallanave and Chang, 2020; Figure 1).

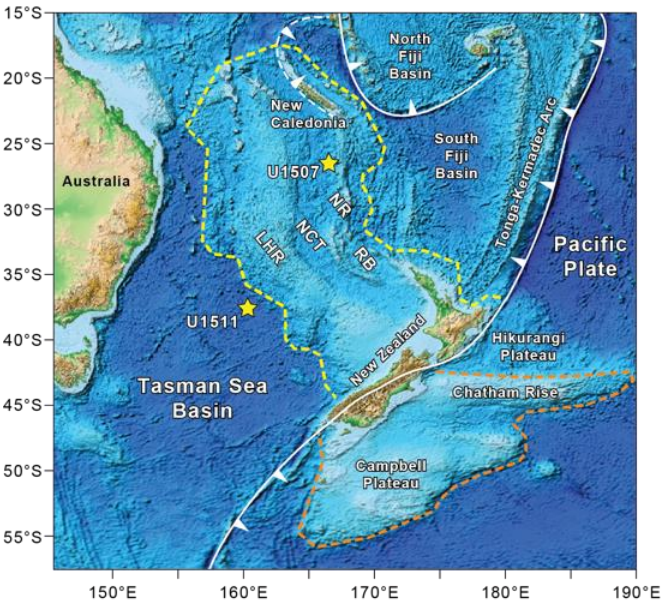

Figure 1: Present-day map of northern and southern Zealandia, enveloped respectively by the yellow and orange dashed line. The yellow stars indicate the location of International Ocean Discovery Program Sites U1507 (26.4886°S, 166.5286°E) and U1511 (37.5611°S, 160.3156°E). Solid and dashed white lines indicate active and inactive subduction zones, respectively, with arrows lying on the overriding plate. LHR = Lord Howe Rise, NCT = New Caledonia trough, NR = Norfolk Ridge, RB = Reinga basin.

After correcting for paleomagnetic inclination shallowing, typical of sediments, we derived five paleolatitude estimates that provide a trajectory of northern Zealandia past position from the middle Eocene to early Miocene, spanning geomagnetic polarity chrons C21n to C5Er (~48–18 Ma). Generally, our results support previous works on global absolute plate motion, including a rapid 6° northward migration of northern Zealandia between the early Oligocene–early Miocene. However, paleomagnetic-determined absolute paleolatitude is systematically lower, and this difference is significant in the Bartonian and Priabonian (C18n–C13r). This discrepancy may be explained by some degree of true polar wander, a solid Earth rotation with respect to the spin axis that can be resolved only using paleomagnetic data. These new paleomagnetic dataset anchors past latitudes of Zealandia to Earth's spin axis, with implications not only for global geodynamics, but for addressing paleoceanographic problems, which generally require precise paleolatitude placement of proxy data.

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IODP

Decrypting tidal- and Milankovitch-driven sedimentary rhythms in nearshore strata of the Archean Moodies Group, South Africa

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Decrypting sedimentary rhythms in deep-time Precambrian sedimentary archives could mark a quantum leap in the reconstruction of ancient sedimentary environments under boundary conditions dramatically different from today's. Theoretically, Precambrian sedimentary rhythms even hold the potential to quantitatively constrain aspects of the history of the solar system, including Earth-Moon interaction. In practice, however, such reconstructions are hampered by poor stratigraphic control and a very limited number of suitable sedimentary archives. The new drill cores of the ICDP BASE Project in the 3.22 Ga Moodies Group of the Barberton Greenstone Belt (South Africa) are, however, well-suited to reinvigorate long-standing questions regarding the role of astronomical and tidal forcing in the Precambrian. This is because these cores provide a continuous sedimentary record, unaffected by differential weathering and marked by repeating sedimentary patterns at a wide range of depth scales, through a large part of Moodies Group stratigraphic thickness (up to 3.7 km). With this poster, we want to present the main objectives of a proposal recently submitted to the DFG ICDP Priority Program.

It is our ambition to evaluate the following hypothesis: *The imprint of tidal and Milankovitch astronomical forcing can be detected and differentiated from autocyclic processes in some of the oldest shallow-water sedimentary rocks on Earth.* The anticipated results have implications for our understanding of Archean paleo-environments, their sensitivity to different forcing mechanisms, and for constraining the behaviour of our solar system more than 3 billion years ago. The tidal aspects of this project (conducted in Bremen) will explicitly challenge the paradigm that the Archean was a tidal world. In doing so, this project is closely aligned with new insights from tidal sedimentology, and addresses the open question of the role of tides in the Earth's deep time of the Earth. The astronomical *Milankovitch* aspects of this project (conducted in Münster) will evaluate rhythmical sedimentary patterns, their frequency ratios and amplitude modulation patterns on meter and decameter-scales to differentiate allocyclic from autocyclic imprints. The combined assessment of sedimentary cyclicity across time- and depth-scales has never been attempted for Archean systems and could entail a major advance in understanding Archean paleo-environments, Earth-Moon dynamics, and possible relationships between stronger or weaker tides under certain astronomical configuration.

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Towards quantitative interglacial fire-vegetation-climate feedbacks of the high-northern latitudes: the new records of Lake El'gygytgyn, E Siberia

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The ongoing intensification of forest fires in the Siberian Arctic (more area, longer duration, higher intensities) raises concerns if these fires might lead to biome shifts from tundra to summergreen or evergreen boreal forest – with consequences for regional to global biophysical land properties and biogeochemical cycles. Given the short time span of instrumental observations, it is unknown if fire can initiate or support biome shifts under the ongoing amplified warming or if climate drives fire regime and biome changes independently. Lake El'gygytgyn in the Russian Far East is currently surrounded by tundra, but for example during late marine isotope stage (MIS) 12 and "superinterglacial" MIS 11, c. 375-440 kyrs ago, pollen data suggests that biome changed several times there, from a glacial steppe to interglacial summergreen and evergreen boreal forest. In an ongoing DFG project, we investigate fire regime shifts during previous warmer-than-present interglacials, such as MIS 5e, 11c and MIS 101-104, and ask if and which type of fire regime shifts accompanied biome shifts in the East Asian high latitudes.

To enable a quantitative reconstruction of changes in fire intensities and the type of biomass burnt, we analyzed multiple fire proxies. The monosaccharide anhydrides (MAs) are specific biomass burning residues from low-temperature fires analyzed with ultra-high-performance liquid chromatography coupled to a high-resolution mass spectrometer. Sedimentary charcoal reflects mid-to-high intensity fires and was analyzed in sieved fraction > 150 □m and from pollen slides using classical microscopy. MA isomer ratios and charcoal morphotypes were used to reconstruct the type of biomass burnt. We analyzed fire proxy amounts and composition and updated existing pollen-based vegetation reconstructions for the early and late Pleistocene using sediments from ICDP sediment core 5011-1 and compare that with fire proxies in modern lake surface sediments from three, modern-analogue lakes in Eastern Siberia.

We find clear differences in sedimentary fire proxy composition over time, with modern compositions depending on source area of charcoals and MAs. Modern fire-vegetation-relationships are linkable to past interglacial proxy relationships indicating that fire regime change played a role during some, but not all biome shifts. Overall, this new understanding of Siberian sedimentary fire proxies is crucial for a sound, i.e. quantitative reconstruction of long-term fire regime change, to assess the role of fire regime intensification in biome changes during periods of stark warming.

ICDP

NonDC-BoVo Non-Double-Couple moment tensor components and their relation to fluid flow in the West-Bohemia/Vogtland region

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The West Bohemia/Vogtland region is well known for its frequent intraplate swarm activity most likely related to fluid flow from the upper mantle into the crust. However, more data are needed in order to fully understand how these fluid flows can generate such swarms.

This project aims to more reliably resolve the mechanisms of earthquakes, so-called seismic moment tensors. Especially the non-tectonic part (non-double-couple components) of these moment tensors can provide information on the processes evoked by fluid flows. To do so, we use a relatively new measure, rotational ground motions. Two rotational sensors have been installed in the region at the beginning of June 2022, at borehole S1 in Landwüst and at the Czech station Skalna. Because rotational sensors are not as sensitive as classical translational sensors, we expected to measure earthquakes above magnitude 1.5 only (up to ~15 km distance). However, first data showed that we have clear signals of earthquakes as low in magnitude as 0.3. Here, we provide some background information on the project and show first data.

IODP

The opening of the Equatorial Atlantic Gateway and its impact of the mid-Cretaceous climate

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The opening of the Equatorial Atlantic Gateway (EAG) is thought to have had a major impact on Cretaceous oceanography, carbon cycling, and climate. Paleogeographic reconstructions suggest that the EAG opened during the latest Albian to earliest Cenomanian. However, there is a dearth of well-dated paleoceanographic records from areas proximal to the EAG that cover this critical time interval, leading to considerable uncertainty regarding the timing of the onset, depth, and extent of water mass exchange across the EAG. Here, we present new sea water Nd-isotope, bulk geochemical, and micropalaeontological data from two South Atlantic drill cores (Deep Sea Drilling Project Sites 363 and 364) that constrain the onset of shallow (<500 m) and intermediate (<~1,000 m) water mass exchange across the EAG to ~113 and ~107 Ma, respectively. Deep water mass exchange (>2,000 m) was possible by at least 100 Ma, 10 Myr earlier than previously thought. The EAG opening induced more vigorous deep water circulation and ventilation in the South Atlantic, Tethys, and parts of the North Atlantic basins, causing a large-scale reduction in organic carbon burial. We propose that reduced carbon sequestration in the South Atlantic and adjacent basins was a key mechanism promoting long-term climate upheaval that culminated in peak greenhouse conditions during the mid-Cretaceous. Our results may help to reconcile global warming with declining rates of volcanic CO_2 outgassing during the Albian to Turonian.

IODP

Micropaleontological reconstruction of Miocene Ross Sea (Southern Ocean) paleoenvironmental conditions

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IODP Exp. 374 drilled five 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 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. It needs to be proven, that changes in either the formation of Antarctic Shelf Water and Antarctic Bottom Water or the vigor of the wind-driven Antarctic Shelf Current control incursions of CDW onto the shelf and the resultant retreat of the WAIS. The records from Exp. 374 will allow to address this issue by assessing changes in water temperature and ice sheet extent.

This study aims to gain insight into the paleoenvironmental development of the inner Ross Sea and the adjacent WAIS with special emphasis on the Miocene Climatic Optimum and the Miocene Climate Transition. To address changes in productivity, water temperatures and sea ice extent, diatom analysis was applied to selected sediment samples. Changes in assemblage composition provide information on sea surface temperatures, sea ice cover and meltwater discharge. The analyzed section of inner-shelf U1521 displays a 200-meter-thick sequence of diatomite and diatom-rich mudstone, deposited between 16.4 and 16.0 Ma BP, stratigraphically constrained by the *Denticulopsis maccollumii* zone at the top of the Lower Miocene. The sequence is characterized by varying diatom preservation, from poor at the bottom of the sequence to good in the upper part. The analyzed section of outer-shelf U1522 comprises a 200-meter-thick sequence of Upper Miocene diatom-bearing sandy diamictite. Here, the preservation of the diatoms is rather poor across the whole section, but still allows some assumptions on environmental changes.

ICDP

Initial results of the project “DEformation Mechanisms along the Main MArmara Fault (DEMMAF)”: 3D lithospheric structure below the Marmara Sea from gravity modelling, seismic tomography and thermal and rheological modelling

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The North Anatolian Fault (NAF) is a right-lateral continental transform fault that extends from eastern Anatolia to the northern Aegean in the eastern Mediterranean. The NAF is characterized by strong and frequent seismic activity, posing a great risk to the region. The Main Marmara Fault (MMF), is the northern branch of the NAF along the Marmara Sea (NW Turkey) that has produced several major earthquakes (M7+) in the past with a recurrence of about 250 years. At present, there is a 150 km seismic gap along the MMF that has not ruptured since 1766. The MMF seismic gap shows important variability in its along-strike interseismic strain-accumulation with locked and creeping segments. Previous works have shown that variable frictional fault properties and crustal rheological configuration likely influence the mechanical stability and segmentation of the MMF. Therefore, it is important to constrain the rheological configuration of the lithosphere to better assess the role of frictional fault properties and fluids on the seismic behaviour of the MMF.

In this contribution, we show the initial results of the recently funded project within the ICDP priority program of the German Science Foundation, Deformation Mechanisms along the Main Marmara Fault (DEMMAF). The goal of the project is to investigate what controls the deformation mechanisms along the MMF, using data collected at the ICDP GONAF observatory (Geophysical Observatory at the North Anatolian Fault) and a combined work flow of data integration and process modelling approach. In the initial stage of the project, seismic tomography models and gravity modelling have been used to derive a 3D density distribution of the crust and upper mantle and the 3D temperature field of the upper mantle, which are the basis for thermal and rheological numerical modelling. As a result of the modelling, we obtain a quantitative description of the physical state (temperature and long-term strength) of the MMF and its surrounding crust and upper mantle that indicates important variability of the brittle-to-ductile transition depth and of the long-term crustal strength of the region. This bulk rheological configuration will be the basis for a new dynamic forward modelling approach where the links between the frictional properties of the fault and the long-term seismic behaviour will be studied.

In next stages of the project, seismic and strain observations from the ICDP-GONAF site will be integrated with regional observations on active seismicity and present-day 3D deformation field to constrain our forward dynamic numerical models. Finally, numerical simulations of coupled thermo-hydraulic-mechanical processes based on the observation-derived 3D models will complement the workflow to evaluate the first order controlling factors for seismic hazard.

IODP

Are hyperthermal events a persistent feature of greenhouse climates?

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Hyperthermal events of the early Paleogene are characterized by the release of large quantities of carbon to the ocean and atmosphere, rapid warming on a global scale, and carbonate dissolution on the sea floor. Therefore, these events indicate many key elements of the anthropogenically induced carbon release and subsequent global warming, making them a prime target when analyzing how ecosystems react to short-term but large CO_2 emissions. The precise extent of these short-term warming events and whether they are a characteristic feature of greenhouse climates or limited to the early Paleogene period, however, is still up for debate. In this study, a 1.5 Myr time interval of the Late Maastrichtian has been analyzed at a ~5 kyr-resolution to test if hyperthermal events occurred outside the early Paleogene. For two cores in the North Atlantic and tropical Pacific, XRF core scanning, wt% $CaCO_3$ analyses, and stable oxygen and carbon isotope records of benthic as well as planktic foraminifera were generated. Bottom-water and sea-surface temperatures were reconstructed through Mg/Ca measurements of the same foraminiferal tests. Preliminary data for both cores reveal time intervals that share features comparable to the orbitally paced hyperthermal events as they are well-known from the early Eocene greenhouse, suggesting that hyperthermal events are a much more widespread phenomenon of greenhouse climate states than previously known.

IODP

Pliocene to Pleistocene reconstruction of regional versus global ocean oxygenation from eastern Pacific anoxic sediments

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Over the past decades, due to anthropogenic global warming and associated decrease in oxygen solubility, the oxygen concentrations in the oceans have decreased. This has resulted in the expansion of oceanic regions that are highly deficient in oxygen, the oxygen minimum zones (OMZs). Such

zones prevail in the eastern Pacific Ocean as a consequence of high biological productivity and subsequent remineralisation of organic matter, which is driven by the upwelling of nutrient-rich waters. The instrumental records of the modern OMZs only cover the last 150 years, therefore, in order to judge if enhanced anoxia is within or outside the range of the natural variability of the past, the only access is offered by the sedimentary record. In order to reconstruct past redox conditions, we will apply a combination of proxies including different Fe speciations, stable Mo isotopes, redox-sensitive metal concentrations, and bulk sediment N-isotope compositions on sediment cores from OMZs. The cores come from the centre of the Peruvian shelf coastal upwelling ODP Site 680 (later redrilled as IODP Site 12289), which was drilled at a water depth of 250 m and from the DSDP Site 479, in the centre of the Guaymas Basin OMZ (750 m water depth). The anoxic sediments of both locations cover the period from the present to the late Pliocene and the applied proxies are commonly used to reconstruct the strength and modes of past anoxia. Site 680 shows a pronounced glacial/interglacial cyclicity of organic carbon contents reaching up to 15% during interglacials of the Pleistocene, whereas deeper Site 479 shows more uniform organic carbon contents near 3%. In addition, in the shallower Peruvian OMZ, changes in sea level and current strength have exerted control on redox conditions of the water column and sediments.

Besides reconstructing past modes of anoxia, the purpose of this project is also to calibrate Mo and Fe proxies. Recent studies on modern sediments show that, for example, Fe speciation is not only affected by redox conditions, but also by continental/marine weathering and post-depositional transformations. These processes can generate signals in paleoceanographic records that cannot be interpreted in terms of anoxia based on standard approaches in a straightforward way. Regarding Mo isotopes, the data generated from these two geological settings will allow us to track if changes in global environmental conditions caused secular changes in past global seawater molybdenum isotope composition. This will be done by understanding and isolating the effects of local processes on the sedimentary Mo isotopic signals. The resulting data of the two locations will be compared and secular trends may arise, which will allow us to provide more reliable estimates of the extent of global redox changes.

IODP

Chronostratigraphic framework for IODP Expedition 379 (Amundsen Sea West Antarctic Ice Sheet History)

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The Amundsen Sea sector of Antarctica is one of the most vulnerable margins of the West Antarctic Ice Sheet (WAIS). A major retreat of the WAIS would significantly contribute to sea-level rise. IODP Expedition 379 (18 January – 20 March 2019) to the Amundsen Sea was aimed at reconstructing a history of the WAIS on a wide range of timescales from the hypothesized first WAIS advance onto the inner Amundsen Sea continental shelf during the Oligocene to the most recent Pleistocene glacial–interglacial cycle.

Of particular interest is evaluation of the Plio-Pleistocene stability of marine-based WAIS margins with respect to warm deep-water incursions and how the WAIS responded to atmospheric and oceanic warming. Site U1532 is located on the western upper flank of a large sediment drift (informally named ‘Resolution Drift’) on the continental rise, ~280 km north of the Amundsen Sea Embayment shelf edge. Site U1533 is located ~62 km west-southwest of Site U1532 on the westernmost lower flank of Resolution Drift (Fig. 22).

Deposits recovered at Site U1532 include silty clay with dispersed sand and gravel and variable biogenic content. Sediments recovered at Site U1533 consist mainly of silty clay with varying biogenic content and amount of bioturbation and with rare occurrences of diamict and conglomerate. Thin sand and silt beds and laminae occur throughout, and intervals of carbonate cementation and volcaniclastic material were also observed (Gohl et al., 2021). Sediments recovered at continental rise sites U1532 and U1533 provide records that (indirectly) document the configuration of grounded ice on land and advance/retreat of the ice sheet across the shelf. Terrigenous deposits intercalated or mixed with (hemi)pelagic sediments provide clues on the state of the WAIS from the late Miocene to the late Pleistocene (Gohl et al., 2021).

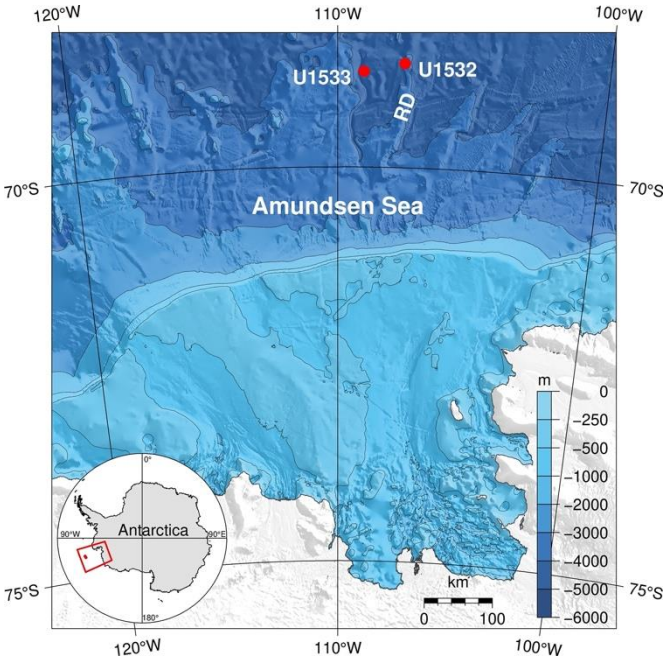

Figure 1: Bathymetric map of IODP Expedition 379 working area with red dots indicating Sites U1532 (68°37’ S, 107°32’ W, water depth 3961 m) and U1533 (68°44’ S, 109°02’ W, water depth 4184 m) in the Amundsen Sea (West Antarctica). RD = Resolution Drift. Map generated with The Generic Mapping Tools Version 6. Data provided by GEBCO Bathymetric Compilation Group 2021.

A reliable shipboard magnetostratigraphy complemented by shore-based full demagnetization of discrete samples was obtained for Site U1532 (maximum drilled depth 794 m). The interpreted magnetic polarity at Site U1532 has been correlated with the Geomagnetic Polarity Timescale of Gradstein et al. (2020). The resulting key paleomagnetic data were then integrated with biostratigraphic data to develop an age model. The magnetostratigraphic record at Site U1532 identified a near continuous latest Miocene to Pleistocene sequence of chrons/subchrons ranging from the base of the Thvera Subchron (C3n.4n; 5.235 Ma) in the lowermost section to the Brunhes Chron (C1n) in the uppermost section at this site. The base of Chron C3r (6.033 Ma) was not observed. Therefore, the oldest sediments recovered at Site U1532 are inferred to be latest Miocene in age (~5.7 Ma). Shipboard demagnetization of Natural Remanent Magnetization at 20 mT at Site U1533 (maximum drilled depth 383 m) and shore-based full demagnetization of discrete samples identified a full sequence of latest Miocene to Pleistocene chrons/subchrons, allowing for a reliable magnetostratigraphy that spans the base of the Thvera Subchron (C3n.4n; 5.235 Ma) to the Brunhes Chron (C1n). Based on the integrated biostratigraphic and magnetostratigraphic age model for Site U1533, the interval shallower than ~37 m is assigned a Pleistocene age; ~37–265 m is assigned a Pliocene age; and ~265–383 m is assigned a latest Miocene age. Below an interval of no core recovery, the oldest cores recovered at Site U1533, Cores U1533B-39R and -43R, are of mainly normal polarity, suggesting an age of the lowermost sediments recovered at this site between the termination of Subchron C3An.1n (6.033 Ma) and the base of Subchron C3An.2n (6.733 Ma). An age of 6.4–6.75 Ma is therefore inferred for the base of Hole U1533B at 381.23 m.

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IODP

Estimation of regional heat flux based on borehole temperatures acquired during logging while tripping with the sea floor drill rig MARUM-MeBo200

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Borehole temperature measurements can be easily conducted at the end of a drilling operation during trip out of the drill string (logging while tripping) without the need for additional operational time. After the final drilling depth was reached, an autonomous borehole logging tool including a temperature sensor is placed at the lower end of the drill string with the sensor part having passed the drill bit and sticking out in the open borehole between bottom of the borehole and drill bit. During trip out the logging tool is hooked up together with the drill string inside the borehole and measures the fluid temperature within the borehole. Stationary phases occur at regular intervals during disconnecting drill rods from the drill string. The analysis of the borehole temperatures during these stationary phases allow the investigation of changes of borehole temperatures with depth and with time. These temperature changes are a function of the geothermal gradient and the perturbation of the temperature field by the drilling action. Here we present results of a pilot study (Freudenthal et al., 2022) based on borehole temperature measurements acquired with the sea floor drill rig MARUM-MeBo200. By modeling the temperature evolution from the start of the drilling operation on, it is possible to analyze the impact of the drilling perturbation on the temperature field and to conclude on the regional heat flux.

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Freudenthal, T., Villinger, H., Riedel, M., and Pape, T. (2022) Heat flux estimation from borehole temperatures acquired during logging while tripping: a case study with the sea floor drill rig MARUM-MeBo. Marine Geophysical Research 44) 37. doi: 10.1007/s11001-022-09500-1

IODP

Preliminary results from sediment cores from the glacially overprinted Labrador Shelf

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The Labrador Shelf is a key area in reconstructing past interactions between the Laurentide Ice Sheet (LIS) and the global thermohaline circulation. It is located in close proximity to the Northern Hemisphere centers of deep-water formation in the Labrador Sea and the northernmost North Atlantic. During past collapses of the LIS at the end of the glacials, strong freshwater pulses were released into the Arctic Ocean and the Labrador Sea/North Atlantic. These fresh-water pulses had a profound influence on the Atlantic meridional overturning circulation (AMOC), which in turn significantly influenced the climate of the Northern Hemisphere. Information on the dynamics of the LIS, mainly from its collapses, is therefore crucial for our understanding of the AMOC and its feedback mechanisms. While the major drainage system of the Eastern LIS, the Hudson Bay in the northernmost part of the Labrador Shelf, is well-investigated as are the areas around Newfoundland and Nova Scotia, large parts of the Labrador Shelf remain relatively unexplored. So far, reconstructions of LIS dynamics are mostly based on information from marine sediment cores taken far off the actual former margin of the LIS. Direct evidence from the shelf, however, is largely missing.

During *Maria S. Merian* expedition MSM84, ca. 100 m of sediment cores were retrieved from the Labrador Shelf. These cores were taken from areas that were heavily eroded by the LIS, but also from a drift body that seems to be largely undisturbed by last glacial ice. Here, we present first results from these cores, including physical properties data, shear-strength measurements and XRF data from selected cores.

IODP

The origin of the Agulhas Plateau at the African-Southern Ocean gateway: Planned research on igneous rocks from IODP Exp. 392

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The opening of the Southern Ocean gateways allowed the emergence of the Antarctic Circumpolar Current (ACC), crucial for the onset of global Cenozoic cooling (e.g., Sijp et al., 2014, Glob. Planet. Change 119; Voigt et al., 2013, EPSL 369/370). South of Africa, the opening was associated with the formation of several large igneous provinces (LIPs) including the Mozambique Ridge, Agulhas Plateau and the smaller Northeast Georgia Rise and Maud Rise. Plate tectonic reconstructions imply that the latter two were once part of the much greater Agulhas Plateau and were separated by subsequent rifting (Parsaglia et al., 2008, Geophys. J. Int. 174). It is debated whether and to what extent the emplacement of these large volcanic features obstructed the exchange of water masses between the Atlantic and the Indian Ocean thereby delaying the onset of the ACC.

The Agulhas Plateau was drilled during recent IODP Expedition 392 (Uenzelmann-Neben, Bohaty, Childress, et al., IODP Exp. 392 Preliminary Report, 2022, in press). Igneous rocks were recovered at two sites on the southern part of the plateau (Sites U1579, U1580) and at one site near its northern edge (U1582). Preliminary (shipboard) data indicate that all sites returned tholeiitic basalts, formed by low pressure (shallow magma chamber) fractionation of mainly olivine and plagioclase (as typical for mid-ocean ridge basalts and many LIP lavas). $^{40}Ar/^{39}Ar$ dating will help to answer fundamental questions regarding the emplacement age of the plateau and its temporal-spatial evolution. Geochemical investigations of the recovered rocks will reveal the nature and source of the magmatism.

The proposed project will focus on the determination of radiogenic (Sr, Nd, Hf, Pb) isotope compositions to further constrain the magma source composition for comparison with other regional and global LIP magmatism. In particular, we want to address the open question whether the Agulhas Plateau, Northeast Georgia Rise and Maud Rise magmatism can all be attributed to the same magma source and setting ("Greater Agulhas") to test the previous plate tectonic reconstruction models. Additional questions are whether a (deep-sourced?) mantle plume initiated the magmatism and its causal relationship to the regional continental breakup and opening of ocean basins.

The isotope data (in combination with the results from age dating and major/trace element geochemistry) will help to constrain the origin and impact of this regional LIP magmatism on tectonic configuration, ocean circulation, and global climate in the mid to late Cretaceous.

IODP

Pliocene West Antarctic Ice Sheet Dynamics -Tying IODP Expedition 379 Drill Records to Seismic Data

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Throughout the past three decades grounding line retreat, accelerated ice flow and ice shelf thinning have characterized the West Antarctic Ice Sheet (WAIS), and its future stability appears to be uncertain. Evidence about the reaction of the WAIS to past warmer-than-present climates including its dynamic behavior to modification in oceanic and atmospheric forcing in the Plio- and Pleistocene may have strong relevance for assessing present and future climate states. During the International Ocean Discovery Program (IODP) Expedition 379, sediment cores from two drill sites were recovered from the Resolution Drift on the continental rise in the Amundsen Sea sector, a key region for understanding past and present WAIS dynamics. Both drill sites provide continuous records from the late Miocene to the Pleistocene including the warmer-than-present intervals of the Pliocene. Drill sites U1532 and U1533 are located on a network of seismic lines enabling a correlation of seismic key horizons and sequence characteristics by core-log seismic integration. We identified an interval with alternating physical properties and high diatom abundance correlating with distinct seismic reflection characteristics. This interval has been dated to 4.2–3.2 Ma and is interpreted to represent a highly dynamic WAIS with prolonged grounding line retreat periods in the Amundsen Sea sector. The extended seismic network allows an extrapolation of the achieved local results to other sediment drift bodies in the Amundsen Sea and Bellingshausen Sea for a larger regional analysis of past WAIS dynamics.

IODP

The opening of the Fram Strait and its influence on sediment transport, climate and ocean circulation between the Arctic Ocean and the North Atlantic

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It is known that during a long period of its Cenozoic history, the Arctic Ocean was isolated from any global thermohaline circulation system (e.g. Jakobsson et al., 2007). Thus, the opening and subsequent widening of the Fram Strait, the only deep-water connection between the Arctic and Atlantic oceans, was a fundamental tectonic process with extensive consequences for the global ocean circulation and paleoclimate evolution as well as for sedimentation processes in the adjacent ocean basins and along the continental margins.

In order to reconstruct both the development of the ocean circulation within and the glacial history of the Arctic-Atlantic gateway we interpreted sediment packages imaged in reflection seismic profiles together with updated stratigraphic information from existing Ocean Drilling Program (ODP) holes (Fig. 1). Our new, high resolution seismic stratigraphy for the Molloy Basin (central Fram Strait) is based on a revised chronology for ODP Site 909 and on a seismic reflection pattern that is better resolved than in previous studies (e.g. Berger and Jokat, 2009).

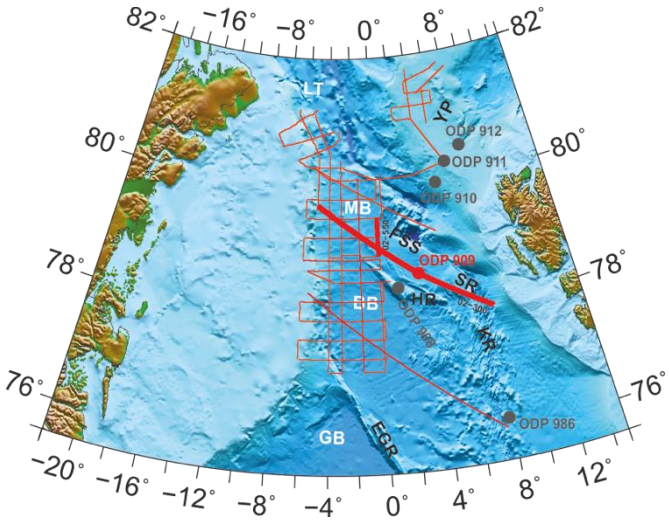

Figure 1: Bathymetry of the central Fram Strait area with locations of re-processed seismic profiles (red lines) and ODP drill sites (dots) and locations of a moored oceanographic array (small orange dots). Geomorphologic features: MB: Molloy Basin, BB: Boreas Basin, GB: Greenland Basin, YP: Yermak Plateau, FSS: Fram Strait Sill, SR: Svyatogor Ridge, HR: Hovgaard Ridge, KR: Knipovich Ridge.

An improved core-log-seismic integration for ODP Site 909 and crossing seismic reflection profile AWI-20020300 (Fig. 2) was substantial in deriving the new seismic stratigraphy as well as characterizing the seismic units lithologically (Gruetzner et al., 2022). The core-seismic integration was combined with a revised magnetostratigraphy calibrated by new palynomorph bioevents which shifts previously used stratigraphies for ODP Site 909 (e.g. Myhre et al., 1995) to significantly younger ages in the time interval from c. 15 Ma to 3 Ma. The new stratigraphy implies that prominent maxima in coarse sand particles and kaolinite, often interpreted as evidence for ice rafting in the Fram Strait occur at c. 10.8 Ma, c. 3 Myr later as previously inferred. In the late Tortonian (< 7.5 Ma), sediment transport became current controlled, most probably through a western, recirculating branch of the West Spitsbergen Current. This current influence was strongly enhanced between c. 6.4 and 4.6 Ma and likely linked to the subsiding Hovgaard (Hovgård) Ridge and the widening of the AAG. Late Pliocene to Pleistocene seismic reflectors correlate with episodes of elevated ice-rafted detritus input related to major steps in Northern Hemisphere ice sheet growth such as the prominent glacial inception MIS M2 and the intensification of Northern Hemisphere glaciation starting at c. 2.7 Ma.

Tracing the most prominent reflectors in a dense net (~5800 km) of re-processed seismic profiles allowed us to extrapolate these events into the Boreas Basin and towards the adjacent Northeast Greenland continental margin. Subsequently compilations of updated digital isochron and depth-to-horizon maps were used to map depocenter geometries of current controlled sediments and mass-transport deposits within the Arctic-Atlantic gateway.

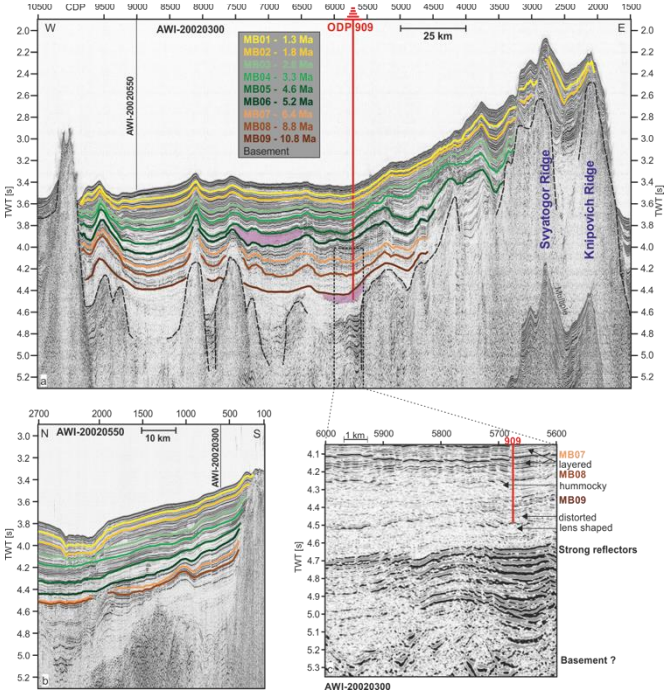

Figure 2: Time migrated and interpreted section of multichannel seismic reflection profile AWI-20020300 across ODP Site 909 (red vertical line), regional reflectors MB01 to MB09 are traced in brownish (Miocene), greenish (Pliocene) and yellowish (Pleistocene) colours. Dashed black line marks acoustic basement. Magenta areas mark debris lobes. (b) Seismic profile AWI-20020550 crossing at CDP 9007 in south-north direction. (c) Close up of profile AWI-20020300 showing the reflection patterns at the base of Site 909.

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IODP

Climatically controlled sedimentation dynamics and export productivity at IODP Site U1537 in the Scotia Sea (Southern Ocean) over the past four glacial cycles

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The Scotia Sea in the Southern Ocean (SO) today is a hydrodynamically important area where Antarctic Bottom Water (AABW) that is previously formed within the Weddell Sea is vigorously mixing into the Antarctic Circumpolar Current. Furthermore, the Scotia Sea is the area where most icebergs that are shedding off marine-based portions of the Antarctic Ice Sheet are drifting out of the Weddell Sea within the so-called “Iceberg Alley”. During past glacial cycles, the position, dimensions and volume transport of the ACC and AABW were substantially different from the modern configuration.

This IODP research proposal, aimed to be realised in the framework of a PhD studentship, seeks to identify the continental source areas of sediments deposited at IODP Site 1537 (59°6.65′S, 40°54.37′W, in 3713 m water depth) that was drilled during Expedition 382 during early 2019. Using the detrital neodymium and lead isotope composition of the bulk and fine (<5 mm) grain size fraction, we will identify continental source areas of terrigenous sediments deposited over the past 450 kyr, hence covering four 100-kyr glacial cycles and five glacial terminations at near-millennial resolution. During key intervals these records will be corroborated by additional argon isotopic analyses on the same sediments. Source areas are expected to be mostly positioned within or close to the Weddell Sea and include older cratonic East Antarctic sequences, as well as relatively young continental crust that is supplied as glacially weathered sediment from the Antarctic Peninsula, Pacific sections of West Antarctica, or dust from Patagonia. We will further generate uranium/thorium isotopic data on bulk sediments to assess sedimentation dynamics (focusing versus winnowing) and assess bottom water oxygen starvation as a function of elevated export productivity in the region.

Overturning dynamics in the Antarctic zone of the SO were likely much reduced due to a northward shift of the oceanic fronts as well as extended sea ice cover during the past glacial climates. As a consequence, less sediment from more remote locations such as East Antarctica should have been transported to the core site, while regional export productivity was also reduced given extended sea ice and lowered Scotia Sea surface water nutrient concentrations due to reduced glacial upwelling. We hypothesize that sediment provenance, sedimentation dynamics, as well as surface ocean export productivity in the Scotia Sea are strongly linked on millennial timescales. Our aim is to provide a new perspective on the degree of connectivity between, and underlying controls of, the position of SO fronts, the status of Weddell Sea Deep Water export, and bottom water oxygen starvation as a function of elevated surface ocean productivity.

IODP

Pliocene Silicate weathering in the South Asian Monsoon domain

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The accelerated rise in global temperatures due to the release of anthropogenically produced greenhouse gases over the past decades has alarming consequences for the future of Earth’s climate system. One crucial component of the climate system is the South Asian monsoon (SAM) given that most South Asian countries depend on this seasonal rainfall for their livelihood. Monsoon precipitation makes Asian rivers the major sediment source to the oceans with seasonal weathering and erosion shaping the landscape. The weathering of silicate rocks is a major sink for atmospheric CO2 on geological timescales and the monsoon climate makes tropical Asia the hotspot of silicate weathering today. With billions of people depending on monsoon precipitation and silicate weathering being the Earth system’s natural way to reduce atmospheric CO2, it is beyond doubt necessary to better understand the nature of South Asian monsoon variability in the future. This is possible by studying the South Asian monsoon behaviour during past warm periods of Earth’s history that can serve as a model system for the coming decades of a warming world. This work will therefore focus on the variability of the South Asian monsoon driven silicate weathering during the Mid-Pliocene warm period, the most recent analogue for the warmer climate of the future. Silicate weathering intensity and provenance in the SAM region will be reconstructed for the Pliocene by employing trace and major elements, radiogenic isotopes including Sr, Nd, Hf, Pb and nontraditional stable isotopes such as Li and Si of marine sediments from International Ocean Discovery Program cores in the Bay of Bengal (IODP Site U1445 and U1443) and the Andaman Sea (IODP Site U1448A). These data will have the high resolution required to enable driving factors to be distinguished when combined with direct proxies for monsoon precipitation strength and local climate. Differences between the sites will reveal spatial heterogeneities of SAM strength and silicate weathering across the region and the relationship between SAM strength and silicate weathering in a warmer world.

IODP

Carbon Cycling at the Dawn of the Cenozoic

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The Paleocene – the first epoch of the Cenozoic (66–56 Ma) – is an intriguing, and often puzzling, time interval sandwiched between the charismatic events of the Paleocene-Eocene Thermal Maximum (PETM) and Cretaceous-Palaeogene (K-Pg) boundary. The epoch is relatively understudied, but spans numerous notable climatic and biogeochemical phenomena. In the oceans, the Paleocene saw the drawn-out recovery of calcifying plankton communities after severe extinction caused by the K-Pg impact, followed by one of the largest excursions in benthic marine carbonate δ13C values of the last 100 Myr1 in the form of the Paleocene Carbon Isotope Maximum. On land, an as-yet-unexplained extreme step-change in global weathering regime is indicated by marine carbonate δ7Li values2. More generally, despite benthic foraminiferal oxygen isotopes that suggest a greenhouse climate much warmer than today3, scant proxy estimates of atmospheric CO2 in the Paleocene mostly indicate low CO2 levels more similar to those seen during the relatively colder late Neogene4.

In this talk, I will summarise some of the recent headway we have made in understanding geochemical cycling and ocean chemistry at the dawn of the Cenozoic, immediately after the K-Pg impact. Following this, I will present new benthic and planktic foraminiferal boron and lithium isotope data that address some of the outstanding puzzles of this formative period for the Cenozoic carbon cycle. Our new, higher boron- derived atmospheric CO2 estimates for this interval resolve some of the apparently anomalous3 behaviour of the Paleocene climate system, and in doing so provide a better understanding of the climatic baseline to the PETM.

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IODP

Pacific “ENSO-Modoki” on the rise under global warming conditions? A view from the Pleistocene and the Early Pliocene

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The El Niño-Southern Oscillation (ENSO) in the Equatorial Pacific is one of the most pronounced atmospheric and oceanic phenomenon, affecting year-to-year climate worldwide. In recent decades, a strong warming with a possibly accelerated melting of glaciers and ice sheets in the high latitudes of both hemispheres has been observed to coincide with the emergence of a third ENSO type — “El Niño/La Niña Modoki”, also called Central Pacific ENSO. During El Niño Modoki (La Niña Modoki) events, sea-surface temperature (SST) is higher (lower) in the central Equatorial Pacific relative to SSTs in the western or eastern Pacific. Consequently, ENSO Modoki provokes twin Walker Circulation cells over the Pacific, which strongly differs from the canonical El Niño events with a single Walker Circulation cell over the Pacific. While severe droughts in South and East Asia and increased precipitation over Mexico and the United States has been observed during El Niño Modoki events, the socioeconomical impacts of ENSO Modoki are poorly understood so far. Understanding whether ENSO Modoki fluctuations are following natural variability or whether the increase over the last decades is due to anthropogenic forcing is, however, crucial to mitigate the potential impacts of anthropogenic climate change. The project aims to better understand the spatio-temporal occurrence of ENSO Modoki from a paleo-perspective to improve the predictability of ENSO Modoki variations under future global warming conditions. For this purpose, high-resolution (c. 1–2 kyr) proxy records of SST and subsurface temperature variability will be generated from ODP/IODP sediment cores from the western (IODP Site U1488), central (ODP Site 871), and eastern (ODP Site 846) Equatorial Pacific. The SSTs and subsurface temperatures are calculated by planktic foraminiferal $SST_{Mg/Ca}$ and alkenone-based $U^{K'}_{37}$-reconstructions. Existing age-depth models are refined with higher resolution based on the stratigraphy of stable oxygen and carbon isotopes of benthic foraminifera.

The proxies for all three sites cover two time periods: (i) the Mid-Pleistocene to the Holocene (300 kyr to present) with its alternating cold and warm phases and lower pCO_2 concentrations than today, and (ii) the Early Pliocene (c. 5.154.85 Ma), which is known for similarly high pCO_2 concentrations as predicted for the near future and an ice-free Northern Hemisphere. First high-resolution $U^{K'}_{37}$-SST results for the last 300 kyr (Pleistocene) from the eastern Pacific (Site 846) were compared with existing data from the western and central Pacific. It has been found that a lower east-west SST gradient occurred during the interglacials, suggesting more La Niña-Modoki-like conditions during warmer periods. More detailed insights into ENSO Modoki during even higher pCO_2 concentrations will be provided by comparison with Pliocene data.

ICDP

First results from BASE drilling in the world's oldest well-preserved sedimentary rocks, the Archean Moodies Group (~3.22 Ga), Barberton Greenstone Belt, South Africa

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The up to 3.7 km thick Moodies Group (ca. 3.22 Ga) of the Barberton Greenstone Belt, South Africa and Eswatini, exposes some of the oldest well-preserved sedimentary strata on Earth. Strata were deposited within only a few million years in alluvial to prodeltaic settings, with a dominance of tidal deltas and coastal plains; they provide a very-high-resolution record of Early Archean surface conditions. Moodies Group strata consist of various types of conglomerates, abundant quartzose, lithic and arkosic sandstones, siltstones,

shales, and rare BIFs and jaspilites, all interbedded with tuffs and several lavas. They preserve abundant sedimentary structures and represent a very-high-resolution record of Paleoarchean surface conditions and processes. Widespread microbial mats, early diagenetic vadose-alteration zones and tidal rhythmites are common. Moodies strata provide a unique opportunity to investigate the environmental conditions under which bacterial life spread and thrived on early Earth (and possibly on similar planets).

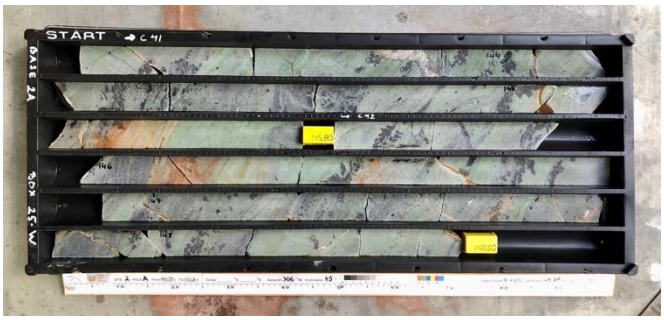

Figure 1: Multiple horizons of early-diagenetic gypsum concretions in tuffaceous sandstones from BASE Site 2 - the world's oldest paleosoils ?

From November 2021 to June 2022, the ICDP *Barberton Archean Surface Environments* (BASE) Project drilled eight inclined boreholes of 280-496 m length through steeply inclined or overturned Moodies Group strata. The unweathered and continuous core record was complemented by sampling in three several-km-long tunnels and by detailed surface mapping. Two to three rigs operated concurrently, delivering twenty to sixty m of high-quality core daily. These were processed in a large, publicly accessible hall adjacent to the museum in downtown Barberton where an exhibition provided background explanations for visitors and related this research project to the recently established Barberton-Makhonjwa Mountains World Heritage Site.

Figure 2: Interbedded, slumped laminated BIF, jaspilites, shale, and siltstone in prodeltaic strata of BASE Site 5A, ca. 3220 Ma.

ICDP

The temporal geochemical evolution of the Tristan-Gough seamount chain

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The Tristan-Gough hotspot track on the African plate comprises the Etendeka flood basalt province, the aseismic Walvis Ridge, and the Guyot Province, which forms a broad and scattered seamount province leading from the Walvis Ridge to the active volcanic islands of Tristan da Cunha and Gough (Fig. 1). Although most recent studies provide strong evidence that the Tristan-Gough track was formed by a deep-rooted mantle plume, its complexity contrast with other hotspot tracks. The Walvis Ridge, for example, underwent a multi-stage evolution from EM I (enriched mantle one) to HIMU (high time-integrated 238U/204Pb) type volcanism, which is ~30-40 Ma younger than the underlying EMI basement (Homrighausen et al., 2018). At the southwest end of the Walvis Ridge, the hotspot track becomes geochemically zoned and then splits into subtracks extending to: 1) Gough island with a Gough-type composition, 2) Tristan da Cunha with a Tristan-type flavor, and 3) a potentially Center-type track (Fig. 1 & 2; Class et al., 2014, Class et al. 2015).

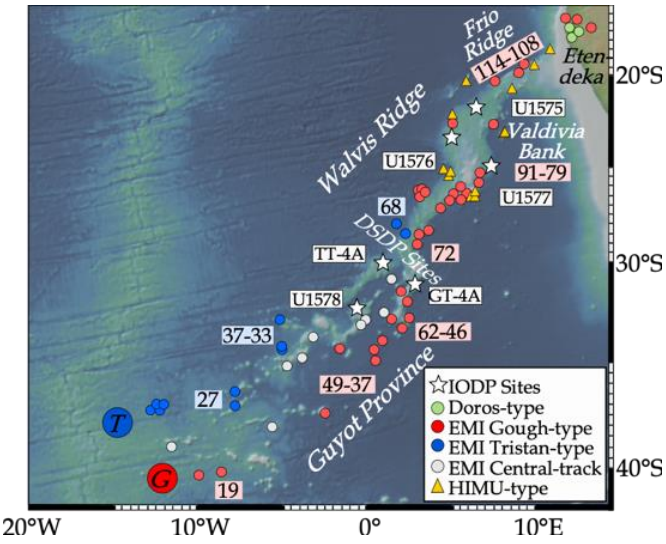

Figure 1: Bathymetric map of the Tristan-Gough seamount chain with previous sample sites and drill site of IODP Expedition 391 and 397T (expected drill sites TT-4A and GT-4A).

During IODP Expedition 391 four sites (U1575-U1578) were drilled and we will focus on Site U1575, U1576A & B and the upper ~163 m of Site U1578, including possible samples from the upcoming cores of Expedition 397T (Fig. 1). We have obtained 100 glass samples and 106 whole-rock samples from 25 distinct igneous units for our study thus far. We plan to analyze radiogenic Sr-Nd-Pb-Hf isotope ratios and O-isotope ratios on freshest samples, both glass and whole rock. Our data will be integrated with Sr-Nd-Pb-Hf isotope data from U1577 and the lower ~140 m of U1578 being studied by C. Class at Lamont-Doherty (USA). We will determine major (electron microprobe) and trace (LA ICP-MS) elements on the glass samples and combine these with major and trace element data determined by W. Nelson, K. Potter and J. Shervais on whole rocks and geochemical data from volcaniclastic deposits (D. Buchs). The combined data will be used to evaluate magma chamber and source (e.g. melting) processes downhole (through time). Finally, we will select a representative set of samples for W-isotope analysis, in order to evaluate if there is a possible contribution of Hadean mantle heterogeneities to any of the geochemical types. Our Sr-Nd-Pb-Hf-O isotope data set will be integrated with Re-Os isotope ratios being analyzed by W. Nelson and Mg-Fe-Zn isotopes by X.-J. Wang, in order to provide new insights into the temporal geochemical evolution of the hotspot track, the temporal geochemical evolution of individual drill sites, and the origin of mantle heterogeneities.

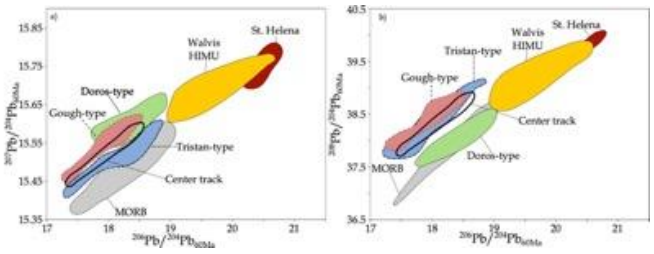

Figure 2: Geochemical diversity of the Tristan-Gough volcanic lineament on Pb isotope diagrams (modified from Homrighausen et al., 2019, Zhou et al., 2020, Class et al. 2014, and Class et al. 2015).

In addition, we plan to address specific questions at each drill site. At Site U1575, ship-board pXRF and ICP-AES data show a central interval with low-Ti basalts (TiO2 < 2 wt.% with MgO > 5 wt. %). In contrast to the expected Gough-type composition (Fig. 1), low-Ti content could indicate a Doros- or Tristan-type composition suggesting a compositional change between the

various EM I-types in a stratigraphic context, which has not been reported so far. With isotope data, we will be able to characterize the EM I-type flavor, which could either extend the geochemical zonation to the early plume tail stage or show that the Doros-type is also present at the transition from plume head to plume tail stage. Site U1576 range from tholeiitic basalts to basaltic andesites, a composition that has only been recognized once previously in the hotspot track. If these rocks are connected through fractional crystallization, we would expect their isotopic compositions to be similar. This site will also provide an important test as to whether the geochemical zonation of the Tristan-Gough hotspot extends further north along the Walvis Ridge than previously recognized, extending zonation more than 10 Ma into the >80 Ma portion of the hotspot track. Major and trace element and isotope data from Sites U1576 and U1577 (Nelson, Potter, Shervais and Class) will also be used to test if the Valdivia Bank plateau overlies stranded continental slivers. Finally, site U1578 samples, together with possible samples from Expedition 397T, will be used to evaluate if the proposed Central track represents a distinct (fourth EMI type) geochemical end member or simply represents mixing between the Tristan- and Gough-type. Our preliminary data from two glass samples from Hole U1578 show a Gough type composition near the top of the volcanic core section and an intermediate composition near the middle of the recovered core. An additional important question is why the different geochemical types can only be clearly distinguished in Pb isotopes thus far. Can this distinction also be recognized in major and/or trace elements, as well as other isotope systems, in fresh mafic glass and whole rock samples obtained by drilling?

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IODP

Frictional Slip Behavior of IODP Expedition 375 Drilling Samples from the Papaku Fault, Hikurangi Subduction Zone, New Zealand

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The Hikurangi subduction zone, located off the eastern coast of New Zealand's North Island, is known for regularly repeating slow slip events which occur at very shallow depths, possibly reaching the seafloor. IODP Expedition 375 sailed to the Hikurangi subduction zone with the goal of obtaining samples and in-situ measurements from the slow slip-zone of the subduction megathrust in order to investigate the conditions and mechanisms of shallow slow slip. One of the boreholes at Site U1518 penetrated a westward-dipping thrust fault which, based on seismic reflection data, soles into the main décollement at a depth of approximately 5 km below seafloor. From samples recovered from Site U1518 Hole F, the fault zone was identified between depths of 305 and 362 meters below seafloor (mbsf), based primarily on shipboard observations of brittle deformation in the core samples and supported by shipboard porosity measurements. The fault zone is designated as Lithologic Unit II, and is subdivided in to three subunits: IIA is the main fault, IIB is a fault-bounded package exhibiting decreasing deformation intensity with depth, and IIC is a subsidiary fault. The hanging wall, fault zone, and footwall are all characterized as Quarternary silty clay/claystone with minor silt and sand beds.

We tested a suite of samples spanning 237-449 mbsf, from the hanging wall through the fault zone into the footwall, in laboratory friction tests using a single-direct shear apparatus at the University of Bremen. Sample cylinders of ~15 mm height and 25 mm diameter were cut from intact sections of core, with the cylindrical axis oriented parallel to the core axis. The samples were loaded to their in-situ effective normal stresses, estimated from a depth-integrated density profile from shipboard measurements, and were tested at a constant temperature of 20ºC. This procedure of testing samples in an intact condition and under in-situ stress provides the most accurate representation of frictional behavior and preserves any in-situ fabric and lithification. We sheared each sample at an initial velocity of 10 µm/s for 5-6 mm, to establish a steady-state shear strength and microstructure. Following this initial phase, the driving velocity was reduced to 0.0016 µm/s, or 5 cm/yr, matching the plate convergence rate at the northern Hikurangi margin. The samples were sheared at the plate rate for 2 mm, after which driving velocity was increased to 0.005 µm/s to measure the velocity-dependence of friction. For three samples from with the fault zone (one from IIA, two from IIB), the dataset was supplemented with two additional experiments, in which the driving velocity was stepped from 0.005 to 0.5 and 0.5 to 50 µm/s in 3-fold steps. The velocity steps were evaluated for rate- and state-dependent friction parameters using the Matlab code "RSFit3000". Following the shearing experiments, the samples were dried in a low-humidity dessication chamber, impregnated with low-viscosity epoxy, and analyzed for microstructure with scanning electron microscopy (SEM) at Cardiff University.

At the plate convergence rate of 5 cm/yr, the steady-state friction coefficient for samples from within the fault zone ranges from 0.48-0.59, nearly identical to that of the wall rocks (0.47-0.62). For the velocity step from the plate rate to 3x the plate rate (0.0016 to 0.005 µm/s) consistent velocity weakening is observed, with the friction rate-dependence parameter a-b ranging from -0.009 to 0. For the fault zone samples for which we tested an extended velocity range, velocity weakening dominates up to a driving rate of 5 µm/s; for the two fastest steps (5-16 and 16-50 µm/s) velocity strengthening is observed in two of the three samples. These results suggest at cutoff velocity for velocity-weakening friction at around 10 µm/s, where the existence of a cutoff velocity is often invoked as a mechanism for keeping slip instabilities slow rather than allowing acceleration to ordinary earthquake speeds. Microstructural images of the slowest laboratory-sheared fault zone samples show a rather complicated array of prominent fractures and shear zones throughout the sample. With increasing velocity, the deformation appears to appear more localized, such that the experiments with the fastest velocities produced the simplest microstructure, with a single shear deformation plane and limited "off-fault" deformation. Additonal analyses of friction parameters and microstructures are ongoing.

ICDP

Microbial activity in a terrestrial subsurface ecosystem shaped by active CO2 degassing

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The Eger Rift (Czech Republic) is characterized by frequent seismic activity and consistently high CO_2 fluxes, making it a preferred site to study interactions between volcanism, tectonics, and microbiological activity. Pulses of geogenic H_2 during earthquakes provide substrates for methanogenic and chemolithotrophic processes, but little is known about the role of subsurface microorganisms and their cellular processes. To assess the impact of geologic activity on microbial life, we evaluated diversity as well as metabolic attributes of bacterial and archaeal communities surviving under high CO_2 conditions.

We used cell counts and qPCR to assess microbial abundances across sediment and rock samples from a 230 m deep drill core drilled as part of the International Continental Drilling Program's Eger Rift Project. Microbial genomics provided insights into community structure and metabolic potential. Enrichments using minimal media and H_2/CO_2 headspace were set up to evaluate the ability of microbes to thrive under high CO_2 concentrations.

Our investigation revealed a distinct low biomass community with a

surprisingly diverse Archaea population, indicating that both methanogenic as well as autotrophic and acidophilic communities reside in the Eger subsurface. Cultivation efforts allowed us to enrich an active methanogen population, dominated by *Methanobacterium* and *Methanosarcina*, for which we recovered and functionally characterized nearly complete metagenome assembled genomes (MAGs).

Our results highlight the importance of Archaea in the terrestrial subsurface and show that high CO_2 concentrations impact geological structures and shape microbial metabolisms.

ICDP

Adaptive radiations of diatoms and their determinants

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Adaptive radiation is commonly considered as a primary process for generating much of the Earth's biodiversity. This process operates over different temporal and geographical scales, strongly dependent on natural selection, stochastic events and historical contingencies. Radiations are a common evolutionary phenomenon in insular habitats, as exemplified by Darwin's finches on the Galapagos Islands, anole lizards on the islands of the Caribbean, and cichlid fishes in the East African Rift lakes. While the latter systems house radiations in many other groups of aquatic organisms, the mechanisms and causes of adaptive radiation have largely been examined in the cichlids. Here, we investigate adaptive radiations within diverse groups of aquatic diatoms in the East African Rift lakes, the genera *Diploneis* and *Afrocymbella*. We use an integrative approach that combines fossils and densely sampled time-calibrated molecular phylogenies to demonstrate that the two diatom groups have evolved *in situ* within the Rift from a common ancestor in a relatively short time. We then use the phylogenetic framework to correlate diversification rates and trajectories of trait evolution with global climate records to detect a potential climate influence on both. Our findings show that adaptive radiation in diatoms may be more prevalent than previously thought, supporting the general notion of this processes being the major contributor to the Earth's biodiversity.

ICDP

A geochemical perspective on the evolution of Dead Sea brines and its link to Eastern Mediterranean hydroclimate (project PRO-HYDRO)

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Well-known for their geological and natural singularity, brines filling the Dead Sea basin provide an invaluable, yet increasingly more scarce, economic resource supplying water and sustaining brine mining activities and tourism in the region. Having evolved from a marine ingression of the Mediterranean during the Pliocene, Dead Sea brines are currently almost ten times more concentrated than seawater and have a unique chemical composition. The knowledge of how the present-day characteristics were attained and their secular trends in the past, bears a great potential for contributing novel information on the geological, environmental and hydroclimatic processes that operate in the basin, with critical implications for sustainable water and brine management practices, that is however yet to be fully explored. This study investigates the use of the sedimentary record from the ICDP Dead Sea Deep Drilling Project (DSDDP, 2010) and additional new outcrop profiles recovered as part of the project PRO-HYDRO as a geochemical archive for reconstructing past composition of Dead Sea brines. We present boron, carbon, and oxygen isotopes combined with elemental ratios in well-preserved late Pleistocene and late Holocene lacustrine aragonites, capturing a time interval when the lake has seen a major (~200 m), approximately half, reduction in its lake level height. We reconstruct the past boron isotope composition of the brines, and show that the late Holocene Dead Sea was isotopically considerably more enriched than its glacial precursor Lake Lisan. We interpret this in context of evaporate formation and deposition in the basin, and suggest changes between wet (glacial) and dry (Holocene) climate states as the main mechanism controlling the boron isotope composition of the brines on millennial time scales (Figure 1). Our findings shed new on light on the evolution of Dead Sea brines and pave avenue for the use of boron geochemistry as a diagnostic tool for inferring past changes in evaporation, and as a result brine concentration and composition through time.

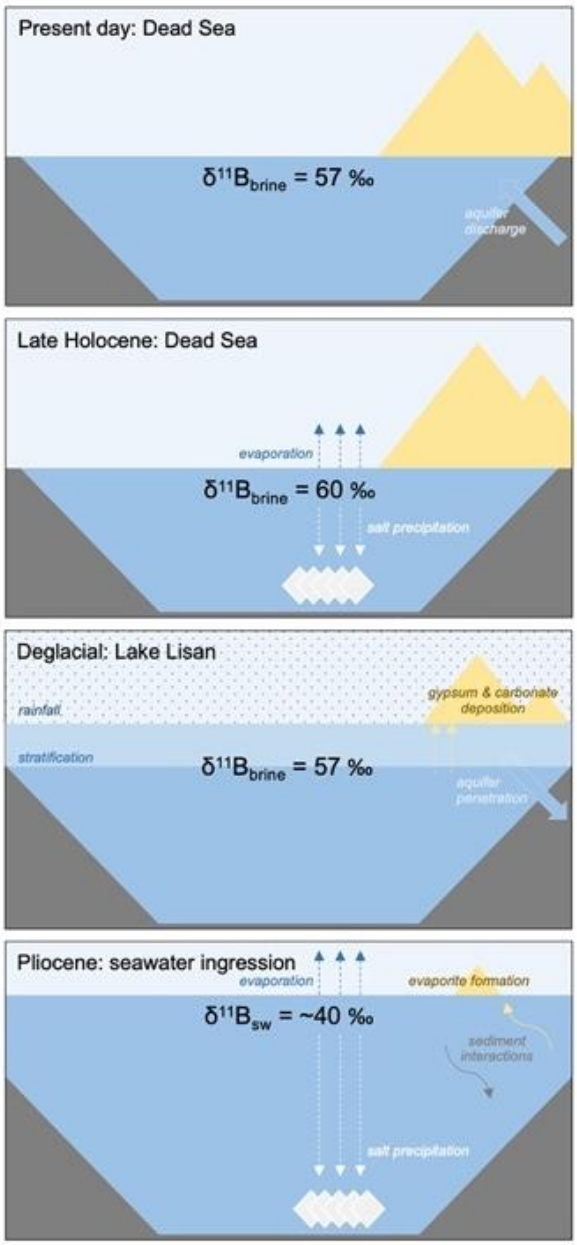

Figure 1. A schematic diagram depicting the evolution and key processes controlling the boron isotope composition of Dead Sea brines since the initial formation of a hypersaline lacustrine body in the basin during Pliocene.

ICDP

Methodological Strategies for Extracting Sedimentary Ancient DNA from Tropical Lake Regions

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The Hominin Sites Paleolakes Drilling Project (HSPDP) provides long records from eastern African paleolakes and the Chew Bahir sediment cores in southern Ethiopia provide sediment samples spanning the last ~620kyrs. Sedimentary ancient DNA (sedaDNA) analysis via high throughput sequencing across these cores can provide a record of past environmental conditions via reconstructing past biodiversity. While the approach has high potential to reconstruct past biodiversity responses to drastic environmental change, the tropical climate of this region increases fragmentation and degradation of sedaDNA, and as a result, the amount of analyzable ancient DNA decreases over time. The results of a pilot study found that the number of less abundant eukaryotic sequences could be increased by target enrichment via hybridization capture of barcode regions[2]. In the study presented here, we explored the effect of different DNA isolation protocols, sediment type, and age of sediment samples on the size and quality of sedaDNA extracted from Chew Bahir cores. For this purpose, sedaDNA from 10 sediment samples aged between 4,000 and 200,000 years BP was isolated using five different isolation protocols. Next, single-stranded libraries were prepared for all samples and shotgun-sequenced reads were analyzed to compare the size and quality of aDNA among the samples. Our initial results indicate that the amount of DNA varies significantly depending on the DNA isolation protocols rather than the age of the sediment sample. Also, Phosphate buffer can cause release of modern DNA from living organisms (microorganisms from the deep biosphere) in the sediment, especially in sediment samples that have a higher DNA binding capacity. Therefore, comparing the yield of different extraction methods is an important consideration when designing sedaDNA studies from tropical regions.

ICDP

The TephroMed project: Using tephra to precisely synchronise two key palaeoclimatic ICDP records of the eastern Mediterranean region

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The eastern Mediterranean region is located between contrasting climatic zones and precipitation regimes, the humid Mediterranean climate to the north and the hyper-arid Saharo-Arabian desert belt to the south. Important sedimentary archives from lakes allow past hydroclimatic variability to be reconstructed using multiple proxies. However, problems associated with chronological uncertainty can prevent insight into regional climatic (a)synchronies. The application of using isochronous chronological markers of tephra (volcanic ash), both visible and non-visible (cryptotephra), can be a powerful tool in correlating palaeoclimatic records, particularly over vast distances.

The TephroMed project aims to precisely synchronise two important ICDP palaeoclimatic records from eastern Mediterranean through the use of tephrostratigraphic investigations: Lake Van, Turkey (PALEOVAN, Litt et al., 2014) and The Dead Sea, Israel (DSDDP, Stein et al., 2011). Both records have undergone palaeoenvironmental and climatic reconstructions which have indicated contrasting past regional responses to large-scale climatic events (e.g. Finne et al., 2019; Neugebauer et al., 2015). Though both records are dated through absolute and relative methods (radiocarbon, U-Th, varve counting, wiggle-matching), inherited large chronological uncertainties do not allow detailed insight into the potential climatic time-transgressive nature between the two sites. Yet, both records have tephra deposits within their lacustrine sediments, highlighting the potential to facilitate the alignment of both records using tephra (Neugebauer et al., 2021).

Here, we present new major and minor element volcanic glass chemical data from several tephra layers from both Lake Van and the Dead Sea ICDP cores. New geochemical data from fourteen selected visible tephra layers in Lake Van will be presented. In addition, preliminary cryptotephra results from the Dead Sea will be given, and with the use of statistical methods, volcanic glasses are correlated to potentially several volcanic regions within the Mediterranean (e.g. Anatolia, Italy). With this new data, the results can help to facilitate a chronological alignment between Lake Van and the Dead Sea along with other important climatic archives in the Mediterranean. As a result of these findings, we can now start to answer questions associated with regional expression of past climatic events and their temporal transgression.

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IODP

Last deglacial environmental change in the tropical South Pacific (Tahiti) from IODP Expedition 310 corals

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Environmental seasonality is of considerable importance to improve model projections of future climate change through retrospective simulations of past climates, but quantifiable evidence of the annual cycle of temperature, salinity, and rainfall from geological archives is sparse. Fossil shallow-water corals provide a unique but relatively rare archive of sea surface temperature seasonality for the tropical ocean and can be precisely dated by the U-series method. Coral climate reconstructions from the Atlantic suggest that temperature seasonality of the tropical surface ocean is controlled mainly by orbital insolation changes during interglacials, even during periods of substantial climate perturbations and abrupt sea-level rise (Brocas et al., 2019). However, comparable information from deglacial corals is still rare.

In this study, Porites coral samples collected during the Integrated Ocean Drilling Program (IODP) Expedition 310 “Tahiti Sea Level” in 2005 (Camoin et al., 2007) were analysed to reconstruct changes in seasonality and mean

climate conditions during the last deglacial transition. Previous studies have utilized some of these samples for seal level reconstructions (Deschamps et al., 2012; Thomas et al., 2012) and coral-based climate reconstructions (Asami et al., 2009; DeLong et al., 2010; Felis et al., 2012; Hathorne et al., 2011). Building on this previous work, we present 170 monthly resolved new annual cycles in Sr/Ca, δ18O, and δ13C obtained from 20 Porites colonies that cover the last deglacial ranging from the Early Holocene (9.06 ka BP) to Heinrich Stadial 1 (15.15 ka BP) with major clusters in the Bølling/Allerød warm period and around Meltwater Pulse 1A, as well some records from the Younger Dryas cooling. Furthermore, samples from modern Porites colonies were collected from Tahiti reefs in the proximity of the sampling sites of IODP Expedition 310. These modern records served as a present-day benchmark for calibrations of proxy data and to robustly assess the uncertainties in our reconstructions.

Reconstructed deglacial sea surface temperature seasonality was reduced (2.2 °C) compared to modern (2.8 °C) demonstrating that temperature seasonality primarily follows variations in insolation seasonality. Mean coral SST variability through the deglacial suggests an influence of Northern hemisphere climate events, such as the Younger Dryas cooling (-1.8±1.0 °C) or the Bølling/Allerød warming (-0.1±1.0 °C) on the tropical South Pacific. Deglacial coral oxygen isotope records point to dryer conditions at Tahiti, likely due to a northward migration of the South Pacific Convergence Zone (SPCZ). During the Younger Dryas, high values in SST seasonality (2.9 °C) and coral δ18O-based salinity reconstructions suggest a reduced mixed layer depth and enhanced influence of the South Pacific Subtropical Gyre due to SPCZ inactivity. Linear extension rates that are a proxy for coral growth rates, were reduced (0.81cm year-1) compared to today (1.56cm year-1), likely as a result of less favourable thermal conditions.

Overall, these findings demonstrate how global climate processes, such as deglacial temperature fluctuations (e.g. Younger Dryas cooling), as well as orbitally controlled variations in insolation seasonality exert a first-order control on deglacial tropical climate seasonality and mean conditions. Second, local climate processes, such as meridional shifts of the SPCZ position influenced climate conditions at Tahiti. These results contribute to an improved understanding of the seasonal response of tropical Pacific climate variability during phases of abrupt perturbations on glacial-interglacial timescales and are of high relevance for projections of future tropical Pacific climate variability and its global teleconnections on society-relevant timescales.

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IODP

Petroleum formation in subsurface hydrothermal sediments is a potential source of recalcitrant dissolved organic matter to the deep Pacific Ocean

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One of Earth's largest reservoirs of organic carbon is oceanic dissolved organic matter (DOM). It comprises about 662 Pg carbon, exceeding a residence time of millennia (Hansell et al., 2009). To date, the reasons for its stability and its role in past and present carbon cycles are enigmatic. We can identify and quantify only a few percent of the recalcitrant oceanic DOM stock. So far, two recalcitrant DOM pools with petagram sizes have been identified: dissolved organic sulfur (DOS, 7 Pg) and dissolved black carbon (DBC, 12 Pg) (Coppola et al., 2022; Ksionzek et al., 2016). Oceanic DOS is an essential player in biogeochemical cycles and it is thought to originate from primary production or abiotic sulfurization of organic matter in sulfidic environments. DBC consists of condensed aromatic structures formed during the incomplete combustion of biomass and fossil fuels on land. DBC is transported to the ocean via rivers and aerosols. Current estimates reveal a discrepancy between global DBC fluxes and radiocarbon ages of oceanic DBC, indicating inconsistencies in our understanding of its sources and processing in the ocean (Coppola et al., 2022). A recent study identified asphalt leachates as DBC source in the Gulf of Mexico (Brünjes et al., 2022). Additional potential sources of pyrogenic DBC may be high-temperature oceanic environments such as hydrothermal systems. We therefore hypothesize that hydrothermal heating of deep subsurface sediments generates and releases large amounts of reactive, as well as recalcitrant, DOM, including DOS and DBC.

In our study, the Guaymas Basin - a young active spreading center - serves as a hydrothermal model system. Sill and magma intrusions into the sediment result in thermal alteration of organic matter changing porewater chemistry and releasing large amounts of DOM. At high temperatures, thermal cracking of sedimentary organic matter leads to petroleum formation. Large amounts of low molecular weight organic acids, hydrocarbons, and dissolved inorganic carbon are released into the water column by fluids emanating from sediments above magmatic intrusions (Lizarralde et al., 2011). Previous studies have shown that some petroleum-derived DOM is bioavailable in the Guaymas Basin supporting active microorganisms at the sediment surface and the overlaying water column (Teske et al., 2019). However, the fate of hydrothermally generated recalcitrant DOM, such as DBC and DOS, and its contribution to the DOM pool in the deep sea are still unknown.

We obtained porewater samples and sediment cores collected during IODP Expedition 385 in November 2019. Hot water extractions (W_{ex}) of sediments were performed to simulate hydrothermal mobilization of organic matter. We determined the molecular composition of solid-phase extracted (SPE)-DOM in W_{ex} and porewater samples using Fourier-transform ion cyclotron resonance mass spectrometry (FT-ICR-MS), and quantified DBC as well as DOS concentrations Our results show that DOM is characterized by lower molecular masses and lower oxygen contents with increasing sediment temperature, likely due to thermal alteration of organic matter. Increasing DBC concentrations with depth suggest the release of polycondensed aromatic DOM from hydrothermal petroleum formation. Our experiments revealed a higher potential for mobilization of dissolved organic carbon and DBC from sediments that were not directly exposed to elevated temperatures (<30°C). DOS concentrations were high at intermediate temperatures (<40°C), where microbially produced sulfide is probably abiotically incorporated into DOM. Therefore, sulfurization of DOM and thermogenic formation of DBC appear to be important mechanisms for the formation of recalcitrant DOM in hydrothermal settings. Hydrothermally driven advective porewater flow likely transports the recalcitrant DOM into the overlying water column, thereby contributing to the deep oceanic DOM pool.

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IODP

Ecosystem change in SE Africa during critical periods of early hominin evolution between 4 and 1.8 Ma

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It is widely accepted that the emergence and disappearance of early hominins in Africa during the Plio/Pleistocene was strongly related to terrestrial ecosystem change. To date, however, the nature, timing, and tempo of ecosystem changes in Africa as well as the characteristics of the climatic forcing behind these terrestrial ecosystem shifts are poorly understood. This holds particularly true for the 'Cradle of Humankind' region that is key for understanding the evolution of the *Australopithecus* and *Paranthropus* genera, due to the general lack of sedimentary archives extending beyond 2 Ma in SE Africa. Near-shore sediment cores from the Indian Ocean off the African coast are well suited to understand the boundary conditions responsible for hominin evolution in Africa and allow us to circumvent the lack of nearby terrestrial archives. They yield direct comparisons between terrestrial and marine proxy records within a robust marine-based age frame. Here we present a multi-proxy record from IODP Site U1478 in the Mozambique Channel, which is a sensitive recorder of sedimentological changes in the Limpopo River catchment area of SE Africa, spanning from 4 to 1.8 Ma. We have generated palynological (including pollen-based climate reconstructions) and plant wax-derived carbon isotopes ($\delta^{13}C$) data that provide insight into vegetation variability. Our new records are compared with previously published inorganic (X-ray fluorescence core scanning; Koutsodendris et al. 2021) and organic geochemical (TEX_{86} and δD_{wax}; Taylor et al. 2021) data from Site U1478, and other regional and global records to provide an ecosystem and climate context for Plio/Pleistocene hominin evolution in SE Africa. The palynological data document a dominance of the savanna (including Poaceae and *Spirostachys africana*) and fynbos-like heathland (including Cyperaceae and Ericaceae) biomes across the study interval. Other important biomes comprise montane forests (including *Podocarpus*), and shrublands (including Asteraceae). Glacials are dominated by fynbos-like heathland and interglacials by savanna. Moreover, peaks of montane forest and shrubland pollen percentages occur at 3 Ma and 3.8 Ma, and 2.4 Ma and 3 Ma, respectively. The pollen data document a long-term trend of decreasing savanna and increasing fynbos-like heathland abundances from 2.8 Ma onwards. The pollen-based climate reconstructions show that this ecosystem turnover is associated with a mean annual temperature decrease of 1°C and a minor reduction in mean annual precipitation by c. 50 mm (from c. 750 to c. 700 mm). Independent evidence for a vegetation change at 2.8 Ma is provided by the $\delta^{13}C_{wax}$ isotopes. They show higher $\delta^{13}C_{wax}$ values from that time onwards, which can be interpreted as an expansion of aridity-adapted C_4 plants in the Limpopo River catchment area. Comparison with other proxy records from Site U1478 suggests that this ecosystem turnover is synchronous with a TEX_{86} based sea-surface temperature decline in the SW Indian Ocean by 3°C associated with only a slight decrease in δD_{wax}-based precipitation reconstructions in the Limpopo catchment. Moreover, the timing of the ecosystem change in SE Africa suggests a connection to the intensification of Northern Hemisphere Glaciation during the late Pliocene rather than the onset of the Walker Circulation that occurred at around 2.1 Ma. Altogether, we posit that the major ecosystem change at 2.8 Ma in SE Africa was predominantly driven by the CO_2 decrease during the late Pliocene and early Pleistocene that facilitated the expansion of C_4 plants and the dominance of fynbos-like heathland without a significant decrease in precipitation. In conclusion, our results document a pronounced terrestrial ecosystem change in SE Africa at 2.8 Ma superimposed onto the glacial-interglacial variability, which may have been crucial for the evolution of early hominin species (such as *Australopithecus africanus*).

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IODP

Palynomorph records from IODP-Sites M0059, M0061, M0062 and M0063 – marine and terrestrial ecosystem change and agricultural activity

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The Baltic Sea spans a distance from the 53° to the 66° N latitude and is adjacent to vegetation zones comprising temperate forest with mixed coniferous and deciduous trees in the South and closed boreal forest with taiga-like conditions in the North. It is particularly affected by global warming, which results in intensifying stratification, oxygen depletion, increasing water temperatures and ecosystem alterations. In addition to global warming, additional anthropogenic factors influence the Baltic Sea: input of nutrients and pollutants as well as vegetation altering, e.g. due to agricultural activity. IODP Expedition 347 sediment cores allow to analyse palynomorphs to reconstruct ecosystem changes in the Baltic region. Here, palynological data from four sites from the southwest, the centre and the north of the Baltic Sea are presented. They reveal timing and potential coupling of changes in terrestrial and marine ecosystems and the onset of agricultural land use in coastal areas.

The results show a transition from freshwater to marine conditions around 7500 yr BP at Site M0059. All four sites reveal a decreasing marine influence between 6000 to 5500 yr BP and ca. 3000 yr BP. A subsequent increase in marine influence is only clearly revealed at Site M0059 by high relative abundances of marine palynomorphs at ca. 1000 yr BP. In the central and southern Baltic region, agricultural activity and anthropogenically induced deforestation increased during the past ca. 1000 years, implied by higher abundances of pollen of cultivated grasses such as rye (Secale) and by a relative decrease in non-saccate tree pollen and synchronous increase in sedges, grasses, and herbs pollen (e.g. Kotthoff et al. 2017). Agriculture is paired with high percentages of the aquatic palynomorph Radiosperma corbiferum in the central Baltic Sea, while in the south, it is perhaps connected to an increase of the dinocyst Gymnodinium. Our results imply that the most rapid changes in the terrestrial ecosystems happened during the past millennium under anthropogenic influence.

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ICDP

Seismic data acquisition on Lake Managua (Nicaragua) for the ICDP proposal "Paleoclimate, Paleoenvironment, and Paleoecology of Neogene Central America: Bridging Continents and Oceans (NICA-BRIDGE)"

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The two largest lakes in Central America, Lake Nicaragua and Lake Managua, are situated in the south-central part of Nicaragua. The location and the proposed long existence (at least Pliocene possibly Late Miocene) make these lakes promising targets for scientific drilling within the International Continental Scientific Drilling Program. Drilling objectives of global relevance, assisted by the strategic lakes' location, include therefore (a) development of a Neotropical environmental and paleoclimate record that will extend presently available late Pleistocene-Holocene records back to Neogene times, (b) determination of the times and rates of marine transgressions and regressions, their tectonic and climatic controls and ecological consequences, (c) investigation of recurrence rates and magnitudes of natural hazards such as explosive volcanic eruptions, landslides, earthquakes and hurricanes, (d) constraints on the timing and magmatic compositional changes during shifts of the volcanic arc, (e) linkages between long-term terrestrial and marine environmental records, and (f) correlation of climatic, geologic and (Holocene) anthropogenic influences on biodiversity and limnological variables.

After having successfully conducted a DFG-funded reconnaissance seismic survey on Lake Nicaragua in 2017, an ICDP funded workshop took place in March 2020. During the workshop, 45 participants from 12 countries reviewed the state of research, including existing data of Lake Nicaragua and Lake Managua. Although seismic penetration of the reconnaissance study at Lake Nicaragua was limited to a small area, recorded seismic data suggest the existence of a long and complete sedimentary succession. Therefore, workshop participants concluded that a three-phase strategy for the proposed research would be most beneficial. The first phase (Phase 0) aims at the recovery of >10 m long piston cores at Lake Nicaragua and additional seismic data collection of Lake Managua. The seismic data collection was approved in the last DFG ICDP call. Data collection is planned for early 2023. Here we present some previous results and plans for data acquisition. A complementary proposal to characterize the upper part of the sedimentary succession beyond the Holocene, i.e., also glacial sediments, and to prove drillability of the identified seismic window, which is a prerequisite to submit a mature full ICDP proposal, is currently under review in the DFG priority program.

IODP

Pliocene–Pleistocene Antarctic Slope Current modulation of Antarctic Ice Sheet dynamics along the Ross Sea continental shelf break, IODP Site U1523

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International Ocean Discovery Program (IODP) Site U1523 was cored in 826 m water depth on the outer continental shelf of the Ross Sea during IODP Expedition 374. This site is uniquely located to monitor variations in Antarctic Slope Current (ASC) strength, which acts as a barrier to the transfer of warmer modified Circumpolar Deepwater (mCDW) onto the Ross Sea continental shelf. We use multivariate statistical techniques of Principal Component Analysis (PCA) and unsupervised hierarchical clustering on highly resolved core scanning X-ray fluorescence (XRF) data to semiquantitatively characterize the stratigraphic nature of sedimentary packages that reflect depositional changes. These results are compared to major and trace element composition, carbonate weight percent, grain size, and physical property data sets to assess variations in penetration of mCDW onto the continental shelf in the Pliocene and Pleistocene. Our data demonstrate that three sedimentary packages characterize the U1523 Pliocene-Pleistocene record and reflect variability in the depositional environment including the types of water masses bathing the site.

Principle Component Analysis on XRF elemental data (Al, Si, K, Ca, Ti, Mn, Fe, Br, Rb, Sr, Zr, and Ba) identified three major principal components (PC) that together explain 71.1% of the data. PC 1 is clearly dominated by terrigenous elements (Al, K, Ti, Fe), as well as Si, which is found in both the detrital and biogenic fraction; this PC correlates with sand content. We relate this PC with ASC strength, which winnows fine sediment and acts as a barrier to incursion of warmer water. PC 2 contains high scores of Si and Br (a proxy for total organic carbon) and correlates with natural gamma radiation and b*, a proxy for diatom content. We correlate this PC to intervals of increased diatom content suggesting open marine conditions and more productive surface waters. PC 3 is enriched in Ca and to a lesser extent Mn, and correlates well with carbonate content. We relate this PC to warmer conditions allowing for increased abundances of planktonic foraminifera and the presence of mCDW on the shelf, which is less corrosive to carbonate. We use hierarchical cluster analysis to identify the downhole distribution of the three sediment packages. From ~4 to 3 Ma, deposition was dominated by biogenic silica with episodes of increased carbonate content indicating seasonally open marine conditions and relatively reduced winnowing, suggesting decreased ASC strength and regular incursions of mCDW onto the Ross Sea continental shelf. There is a significant change in sediment deposition around the Pliocene/Pleistocene boundary, with a decrease in biogenic silica-dominated sediments and increase in coarser terrigenous sediment, suggesting increased ASC strength after that time. The carbonate-bearing sediment alternates with the sandy terrigenous sediment in the Pleistocene suggesting glacial-interglacial control on ASC strength and incursion of mCDW. Biogenic silica also reappears as a major component of the sediment for short intervals after the mid-Pleistocene transition. These results suggest a transition from subpolar conditions with open, highly productive surface waters in the Pliocene to more ice-proximal glacial conditions in the Pleistocene, which is consistent with depositional motifs identified in the ANDRILL AND-1B drill core. Additional work will place these results into a more detailed age framework to examine glacial-interglacial conditions along this margin of the Ross Sea to elucidate the relationship between the Southern Ocean and Antarctic Ice Sheet dynamics.

IODP

Hydroclimatic changes in subtropical Southeast Africa across the Last Interglacial revealed by plant leaf wax stable isotopes in Zambezi Fan sediments (IODP Site U1477)

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Hydroclimate conditions in subtropical Southeast Africa are generally considered to be significantly affected by future global warming. However, the extent of the supposed hydroclimatic changes is still difficult to assess because of ambiguous proxy records and climate simulations for past warm periods. In this context, investigating regional hydroclimate variability during the Last Interglacial (Eemian or Marine Isotope Stage (MIS) 5e), the most recent time interval with higher temperatures than today, might provide important information about the response of the regional hydroclimate to future warming scenarios. In addition, an improved knowledge of Last Interglacial hydroclimate variability in Southeast Africa can also provide new information about its possible impact on the cultural evolution of the first anatomically modern humans and their migration out of Africa.

To reconstruct past hydroclimatic changes in subtropical Southeast Africa across MIS 5e, we analysed the stable hydrogen isotope composition (δD) of long-chain *n*-alkanes (particularly *n*-C_{29} and *n*-C_{31}) that are preserved in sediments recovered at IODP Site U1477, located ~85 km off the Zambezi River delta in the Mozambique Channel. Long-chain *n*-alkanes are major components of the leaf waxes of higher terrestrial plants and transported from the continent to the ocean by the Zambezi River. As the *n*-alkane δD primarily reflects amount-controlled changes in the δD of regional precipitation at the time of plant growth, it can be used to reconstruct past hydroclimate variability in the Zambezi River catchment. In addition, the stable carbon isotope composition ($\delta^{13}C$) of the long-chain *n*-alkanes allows to track past vegetation changes, i.e. variations in the relative abundance of C_3 (e.g. trees) and C_4 plants (e.g. savanna grasses).

Already within the terminal phase of the Penultimate Glacial (MIS 6) we observe a decrease in the δD of *n*-C_{29} and *n*-C_{31}, starting well before the decrease in the $\delta^{18}O$ of benthic foraminifera that defines the onset of MIS 5e. This δD decrease most likely reflects a humidity increase in subtropical Southeast Africa. Fairly humid conditions prevailed thereafter, interrupted by a distinct episode of relatively high δD values between ~125 and ~119 ka BP, most likely representing an interval of pronounced dryness during the second half of the Last Interglacial. This interpretation is in good agreement with very low *n*-alkane concentrations during this interval, indicating reduced input of terrestrial organic matter by the Zambezi River. In the following, another interval of relatively high δD values is observed around 105–112 ka BP, i.e. already during the Last Glacial Inception, reflecting a second pronounced dry phase that was again accompanied by low terrestrial organic matter input by the Zambezi River. After ~105 ka BP, compound-specific δD values progressively decrease, likely indicating further increasing humidity over Southeast Africa.

Our results document considerable hydroclimate variability in Southeast Africa across the Last Interglacial, highlighting the unique potential of the IODP Site U1477 sediments for reconstructing past hydroclimatic changes in the region. The good temporal agreement of supposedly dry episodes in the region with wet intervals in Northeast Africa indicates that the northward migration of early modern humans out of Africa could have been fostered by antiphased hydroclimatic shifts in Southeast and Northeast Africa.

ICDP

Drilling the Unknown: Proterozoic igneous and Lower Palaeozoic sedimentary rocks below the Caledonian nappe pile – COSC-2 models vs. Reality

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The COSC (Collisional Orogeny in the Scandinavian Caledonides) project is linked to the Swedish Scientific Drilling Program (SSDP) and the International Continental Scientific Drilling Program (ICDP). Its main goal is the characterisation of orogenic processes involving structures, basement and sedimentary successions by a multidisciplinary and international team of geoscientists. The COSC project studies the processes related to the closure of the Iapetus Ocean and the corresponding continent-continent collision between Baltica and Laurentia during Early Palaeozoic times (Fig. 1), when the Baltoscandian margin was partially subducted beneath Laurentia in the mid-late Silurian, forming a Himalayan-type orogen. This collisional mountain belt in western central Sweden is deeply eroded and two sites have been cored down c. 2.27-2.5 km from this segment of the Early Paleozoic Caledonide Orogen. Proposed targets of COSC-2 include the investigations of the detachment, the influence of orogenesis on the basement beneath and the Early Palaeozoic environments on the outer margin of Baltica facing the Iapetus Ocean.

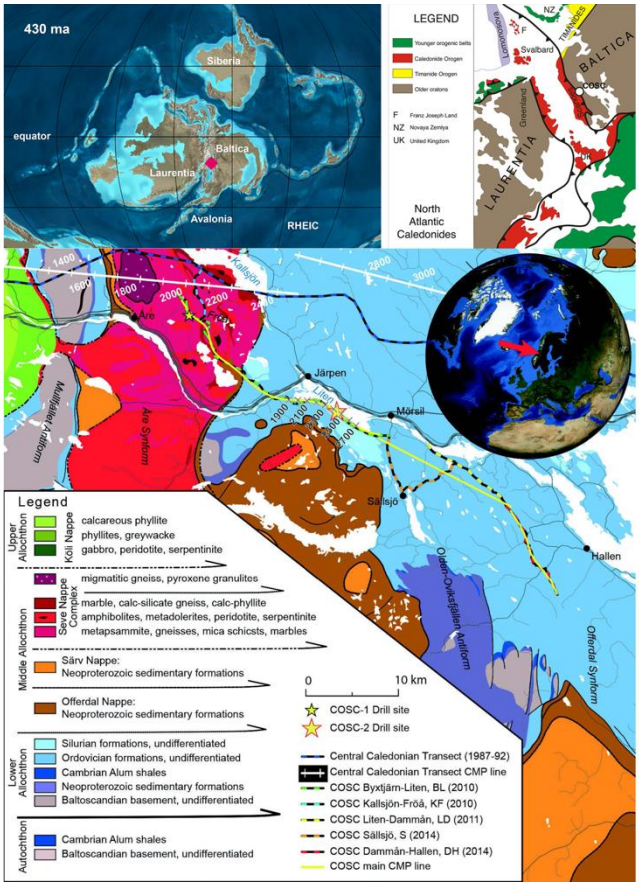

Figure 1: Silurian palaeogeography (upper left) showing the equatorial position of Baltica during the interval of its amalgamation with Laurentia and Avalonia (modified from a file available at the website of Ron Blakey, http://www2.nau.edu/rcb7/; the red diamond shows the position of the COSC drill sites). The palaeogeographic map (upper right; Gee et al. 2010) shows a part of the Caledonian Orogen ca. 60 Ma before the opening of the North Atlanic. The tectonostratigraphic map of the Are–Jarpen area (lower part) from Lorenz et al. (2022) is based on the 1 : 200 000 scale geological map by the Geological Survey of Sweden, I2014/00601 by Stromberg et al. (1984).

COSC-2 aimed to study, based on seismic interpretations and geophysical models, a continuous Lower Palaeozoic sedimentary succession, the main Caledonian décollement in the Cambrian Alum Shale succession, and a Fennoscandian granitic basement (Fig. 2, left). However, the COSC-2 record displays perfectly why deep continental drilling is extremely important. Logging and early studies show that, although we had good assumptions of the subsurface, our model proved to be wrong in several key implications. Scientific drilling recorded an unexpected but very interesting core succession involving a thick porphyry sequence intruded by dolerite dykes instead of Paleoproterozoic granitic basement. In addition, drilling suggested that an imbricate zone with Proterozoic and Cambrian sandstones originating from different settings cover this basement, overlain by a deformed Alum Shale comprising the main décollement and followed by a Lower Palaeozoic siliciclastic succession formed in more outboard and deeper environments. This differs significantly from the interpretation based on the site investigations, which also suggested a main detachment hosted in Alum Shale, but close to the top of the basement and overlain by a zone of imbricates (Fig. 2, right). Recently, detailed geological core descriptions show that there is a continuous sedimentary succession on top of the weathered basement (saprock & saprolith) covered by regolith which is overlain by basal conglomerates. A few meters of heterogeneous sediments, including marls with trilobites, indicate a Lower Cambrian age instead of a Neoproterozoic one, displaying the unusual development of an Early Cambrian basin, which was filled initially, most likely very rapidly, by mostly coarse-grained sediment gravity flows. This sedimentation was interupted by a longer quiet period of Alum Shale deposition (Middle Cambrian/Maolingian through Lower Ordovician/Tremadocian; e.g., Zhao et al. 2022), which transitioned into turbidite sedimentation. This sequence shows fining upward and indicates a general deepening (Tremadocian and younger?). This turbidite succession was previously regarded as a foreland basin fill. However, the local sources of the turbiditic sediments below the Alum Shale and the long time of deposition rather points to a continuous sedimentation in a long-lived pull apart basin that is well preserved beneath the Caledonian nappe pile.

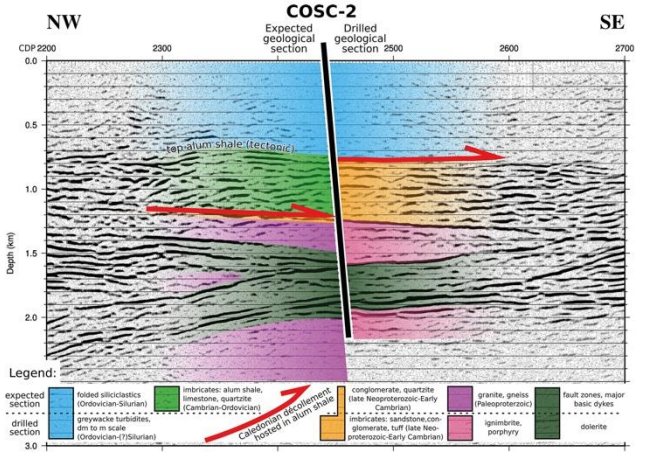

Figure 2: The COSC-2 expected geology (left; after Hedin et al. 2012, Juhlin et al. 2016) and the geology interpreted while drilling (right) superimposed on the depth-converted seismic section that represents the rock in the vicinity of the COSC-2 drill site (after Lorenz et al. 2022).

This COSC-2 succession provides the possibility of detailed sedimentological, stratigraphic, geochemical, geothermal and structural studies. Dating of sedimentary units is most important now for providing a stratigraphic framework for further correlations with geotectonic events, sea-level fluctuations, evolutionary pulses, climate changes as well as for the re-interpretation of seismic models. The well preserved COSC-2 sequence provides a base for many interdisciplinary collaborations and studies performed by different working groups of the COSC science team.

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IODP

Variations in Subantarctic Pacific Surface to Intermediate Water stratification and ventilation during the Pleistocene

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Southern Ocean dynamics and their interaction with the atmosphere are key components for understanding Pleistocene climate change on orbital to millennial timescales. Glacial to interglacial variations in sea-ice cover, upper ocean stratification, biological nutrient utilization and water ventilation play a major role in natural variations of atmospheric CO2 concentrations over the past 800 ka and beyond. The successful realisation of IODP Expedition 383 DYNAPACC to the subantarctic South Pacific closed a critical gap in available sedimentary records from the high-latitude Southern Hemisphere, in particular for the subantarctic Pacific. We use SE Pacific Site U1542 from the Southern Chilean continental margin and locations in the pelagic Central South Pacific, including Site U1541, U1539 and their respective site survey cores from the East Pacific Rise to compare the characteristics of surface to mid-depth thermocline waters between the central and eastern South Pacific, and investigate the vertical structure and formation dynamics of Southern Ocean Intermediate Water (SOIW). We use planktic foraminiferal multi-species isotopes and element ratios comprising shallow and deep dwellers to reconstruct the paleo-physical and -chemical characteristics of surface, thermocline, and deep thermocline Southern Ocean Water masses, in order to understand their long-term dynamics, their sensitivity to – and interaction with – changing climate forcing mechanisms across major climate transitions throughout the last 1.5 Ma. In line with investigating these physical paleo-oceanographic changes, the carbon isotopic gradients from different planktic foraminifers are used to reconstruct the ventilation history between mid-depth and upper ocean waters.

IODP

Evolution of the Laurentide Ice Sheet on the Labrador Shelf reconstructed by geomorphological analysis

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The Labrador Sea is one of the key areas to study climate variations from the Cenozoic to the present, with the Atlantic Meridional Overturning Circulation (AMOC) as the major driver for climate fluctuations in this region. During glaciations, vast areas of Northern North America are covered by thick ice sheets, such as the Laurentide Ice Sheet (LIS). During periods of melting, these ice sheets release significant amounts of freshwater into the North Atlantic and influence the ocean circulation. Open questions concerning the effect of global warming on the AMOC stimulate discussions and studies on the mechanisms responsible for the strength and heat flux of this ocean circulation. Since changes in the AMOC are mainly caused by natural climate fluctuations between glacials and interglacials, it is critical to examine the dynamic behavior of the LIS in detail. However, data on the dynamics of the LIS are mainly derived from sediment cores located far offshore in the Labrador Sea and information from the Labrador Shelf is limited to Holocene sequences. In 2019, we carried out an expedition to the Labrador Shelf to study the dynamic behavior of the LIS. Our study relied on a combination of bathymetry, sediment echosounding, and 2D high-resolution seismic data. We discovered landforms likely related to the penultimate and older glaciations, which are essential for the reconstruction of the eastern extent of the LIS. Therefore, the new data can be used to propose mechanisms responsible for freshwater pulses into the central Labrador Sea during the Pleistocene and early Holocene. Thereby, the data provide important constraints for the reconstruction of the LIS on the Labrador Shelf. However, a drilling transect from the open marine realm through coastal areas and into the interior of the Canadian shield is required to gain a more detailed understanding of the LIS evolution. The results of this study can be seen as a pre-site survey and provide the basis for more detailed studies in the marine realm which allow the recovery of paleoclimate records.

ICDP

Cyclostratigraphy of the Early Jurassic Sinemurian stage deduced from downhole logging data of the Prees-2 core (England) as part of the ICDP JET project

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In the end of 2020, an approx. 650 m deep core was drilled at Prees in Shropshire, England, as part of the ICDP JET project (Integrated Understanding of the Early Jurassic Earth System and Timescale). The main objective of this project is to obtain and characterize a complete and continuous sedimentary archive of the Early Jurassic (200-175 Ma) which will provide a "master record" for an integrated stratigraphy (bio-, cyclo-, chemo- and magnetostratigraphy) of this period. In addition, the project will allow the reconstruction of the local and global palaeoenvironment and the driving mechanisms and feedbacks responsible for environmental changes in the Early Jurassic.
The analysis of geophysical borehole measurements contributes to interpretations of sedimentary cycles related to orbital parameters, insolation and therefore to paleoclimatic history. Here, downhole logging data of the Prees-2 borehole is used to construct an astronomical timescale for the Sinemurian stage, which will be combined with other published astrochronological constrains on the duration of the earlier Hettangian and later Pliensbachian stages to receive a continuous timescale for the Early Jurassic.
Cyclostratigraphic analyses are performed by hand and statistically confirmed by using the "astrochron" package for the R programming language (Meyers 2014, R Core Team 2021). The results lie in the range of other estimations of the Sinemurian duration and assign ~6.5 Ma.

IODP

The AMOC strength of the last glacial cycle

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The climate of the last glacial cycle was characterized by long-term variations and by repeated millennial-scale oscillations. During northern stadials, ice cores from the southern hemisphere suggest that Antarctica warmed, and each subsequent rapid northern hemisphere warming shortly was followed by cooling at high southern latitudes (Buizert et al., 2015). Explanations for this inverted interhemispheric behavior of climate changes require a mechanism for partitioning heat on a planetary scale, either through atmospheric transport or via the Atlantic Meridional Overturning Circulation (AMOC; Rahmstorf, 2002; Stocker, 2003; Zhang et al., 2017).

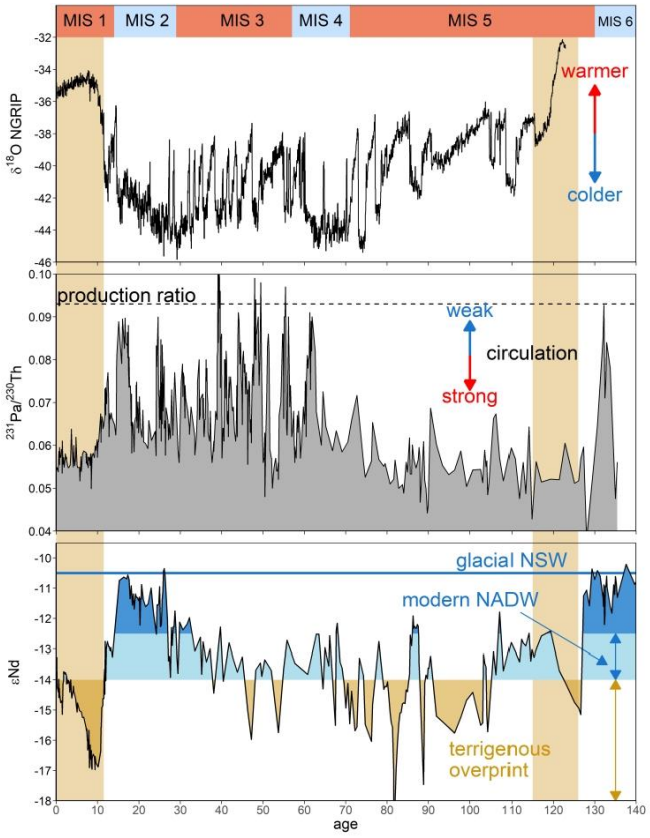

Figure 1: Proxies of ocean circulation from the Bermuda Rise: Upper panel: NGRIP δ18O record (Andersen et al., 2006). Middle panel: 231Pa/230Th record of the last 140 kyrs (McManus et al., 2004; Böhm et al., 2015; Henry et al., 2016). The dashed line shows the 231Pa/230Th production ratio. Lower panel: εNd record (Böhm et al., Lippold et al., 2019). Bright blue values indicate the range of the modern NADW. The dark blue values show the Nd isotopic signatures of glacial Northern Sourced Waters(Pöppelmeier et al., 2021). The brown (low) values indicate isotopic signatures which have been overprinted by poorly chemical weathered material and are therefore do not represent a water mass signal.

The '^{231}Pa/^{230}Th-McManus04-record', measured from the deep Bermuda Rise (McManus et al., 2004), manifestly mirrored the prominent δ^{18}O curve of the Greenland ice-cores, strongly highlighting the role of AMOC in controlling oceanic heat transport to the northern hemisphere and underpinning its unique paleoceanographic selling point. Subsequently, the region around the deep Bermuda Rise, obviously highly sensitive to AMOC variations (Rempfer et al., 2017), has been the subject of several studies on AMOC reconstructions, also on basis of the εNd water-mass tracer based on Neodymium isotopic signatures (Fig. 1; Böhm et al., 2015; Deaney et al., 2017; Gutjahr & Lippold, 2011; Henry et al., 2016; Jaume-Seguí et al., 2020; Lippold et al., 2019; Roberts et al., 2010). These reconstructions from the Bermuda Rise up-to-date dominate the view on the AMOC evolution of the last ~130 ka as perceived by the (paleo)climatology research communities working on models and/or observations.

However, in the last years the reliability of ^{231}Pa/^{230}Th at the Bermuda Rise was increasingly doubted from the observations of variable strong scavenging by benthic nepheloid layers (BNL) and/or biogenic opal which both add an additional poorly constrained sink for ^{231}Pa and ^{230}Th (Hayes et al., 2015; Keigwin & Boyle, 2008; Lerner et al., 2019; Lippold et al., 2009). Hence, the most recognized paleo-circulation records of the last glacial cycle from the Bermuda Rise, used as benchmark records for the modelling and paleoclimate communities, may be significantly affected by effects not directly related to large-scale AMOC variations. Accordingly, we have to critically re-evaluate former interpretations and identify and analyze locations not affected by non-circulation effects like BNLs or intense fluxes of biogenic opal.

The main goal of the project is, to critically question the up-to-date prevailing, but for plausible reasons not uncontroversial, picture on reconstructed past AMOC evolutions from the Bermuda Rise and to provide more robust estimates and reliable uncertainty ranges. We will pin down the evolution of AMOC during the last glacial cycle (~ 0-130 ka) by providing down-core records from suitable and sensitive Atlantic core sites from up and down stream of the Deep Western Boundary Current. The locations should be characterised by high sedimentation rates, while the variability of particle fluxes, in particular opal, should be small. Based on these requirements, we select IODP Site U1313 (41.0°N, 33.0°W, 3413 m water depth) situated in the mid-latitude North Atlantic and ODP Site 929 (5.9°N, 43.7° W, 4369 m water depth) from the equatorial western Atlantic. Furthermore, ODP Site 929 is located at the border between North Atlantic Deep Waters and Antarctic Bottom Water and is therefore expected to be highly sensitive to any changes in the interplay of these water masses (Howe & Piotrowski, 2017).

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ICDP

Analysis of CO_2 driven microbial behaviour and metabolic responses in the geologically active Eger Rift subsurface

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With frequent seismic activity and consistently high CO_2 fluxes, the Eger Rift in Western Bohemia, (CZ), represents a rare subsurface ecosystem and scientifically relevant location to study microbial behavior and assess the of role of geologically derived compounds or substrates contributing to the development of microbial populations in the deep subsurface [1-3]. Explorations into microbial life in this unique ecosystem also provide the opportunity to address the question of how high CO_2 levels and the associated mineralogy influence microbial community composition and metabolic activity and how this knowledge can be utilized to establish CO_2-based biotechnological production processes. As seismic activity in this region can release H_2, potentially promoting the production of biogenic methane [4], the role of methanogenic Archaea is an additional research interest.

To evaluate microbial distribution and gain insights into microbial processes associated with elevated levels of CO_2 we evaluated diversity as well as metabolic attributes of bacterial and archaeal communities in drill core samples from a recent drilling campaign. This approach includes direct assessment of native microorganisms through qPCR, fluorescent cell microscopy, and 16S rRNA and metagenomic sequencing as well as the enrichment of potentially CO_2 utilizing microbial communities and subsequent genomic characterization of their metabolic potential and activity.

Analysis of 26 sediment and rock samples, covering depths between 17 m and 230 m revealed overall low biomass, but also demonstrated microbial life to persist in the terrestrial subsurface below 200m. Genomic explorations provided novel insights into a fascinating, potentially CO_2 adapted, microbial community, dominated by rhizome and soil associated Proteobacteria and highlighted by an unexcepted archaeal diversity. The identification of acidophilic and methanogenic taxa suggests CO_2 and potentially the

periodically, through seismic activity released H_2 to be important driving forces in this unique ecosystem. Reconstruction and annotation of several MAGs, from both core material and enrichments, provided first insights into microbial processes driven by CO_2.

Going forward metagenomic and metatranscriptomic approaches will be used to specfically investigate cellular processes under high CO_2 conditions to identify pathways and biomolecules utilizing the biological resources evolved in the CO_2-rich geological as a basis to develop biotechnological processes using CO_2 as substrate for microbially synthesized products.

IODP

Multiproxy paleoceanography from Broken Ridge pinpoints the onset of Tasman Leakage at 6.6 Ma

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Inter-basinal heat and water exchange play a prominent role in driving global climate change on astronomical timescales, as part of the global thermohaline circulation. Tasman Leakage connects the Pacific and Indian Oceans at an intermediate water depth, south of Australia. Therewith, Tasman Leakage advects heat toward the Indian Ocean, and ultimately toward the Agulhas system. Hence, Tasman Leakage constitutes a non-negligible part of the present-day thermohaline circulation. The onset of Tasman Leakage likely occurred sometime in the Late Miocene, but precise geochronology for the establishment of this inter-basinal connection is still lacking. Moreover, Tasman Leakage sensitivity to astronomical forcing remains to be constrained in detail. To understand Tasman Leakage on astronomical timescales, we present a new Miocene-to-recent multi-proxy dataset from Ocean Drilling Program (ODP) Sites 752 and 754, cored on Broken Ridge (30°53.475'S), southeastern Indian Ocean.

The dataset consists of new X-ray Fluorescence (XRF) core scans that provide element contents for 18 different elements, along with benthic carbon and oxygen stable isotopic records at 4 cm resolution. The XRF-derived Ca/Fe record is paced by 405-kyr eccentricity between 22 Ma and 13 Ma (early-middle Miocene), but then becomes more sensitive to obliquity and precession forcing. The new high-resolution benthic d13C record confirms the onset of Tasman Leakage in the Late Miocene, more specifically at 6.6 Ma. This is when the Broken Ridge benthic d13C signature no longer reflects an Antarctic Intermediate Water signal. The benthic d18O record shows a strong ~110-kyr eccentricity imprint, indicating that Tasman Leakage might be most sensitive to this astronomical parameter. We conclude that the Neogene nannofossil oozes, preserved on Broken Ridge, constitute an excellent paleoceanographic archive that allows us to fingerprint Tasman Leakage sensitivity to astronomical forcing.

ICDP

Abrupt millennial-scale oscillations during MIS3-2 registered in the sediments of tropical Lake Petén Itzá

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Lake Petén Itzá (Guatemala) holds one of the oldest paleoclimatic records in the northern neotropical region (Fig. 1). The lake is located in a highly biodiverse and climate-sensitive area. Sediments related to ICDP drilling project PISDP span a 400 kyr record of hydrological changes, of which we investigated the last 80 kyr in high-resolution (Martínez-Abarca et al. 2022).

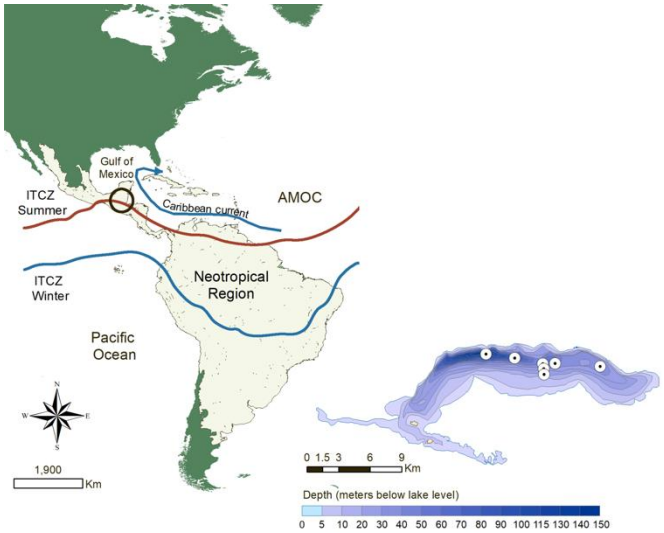

Figure 1: Geographic map with the location of Lake Petén Itzá. The lake is located in Guatemala and its position is indicated with a black circle. The Neotropical region is shown in beige. ITCZ positions during summer and winter are shown. The warm Caribbean surface current is indicated. It is shown the ICDP drilled sites with white dots along the lake.

Our geochemical record presents changes in runoff, evaporation, organic matter sources and redox conditions associated with lake level variations during Marine Isotope Stages (MIS) 3 (57-29 cal ka BP) and 2 (29-15 cal ka BP) (Fig. 2).

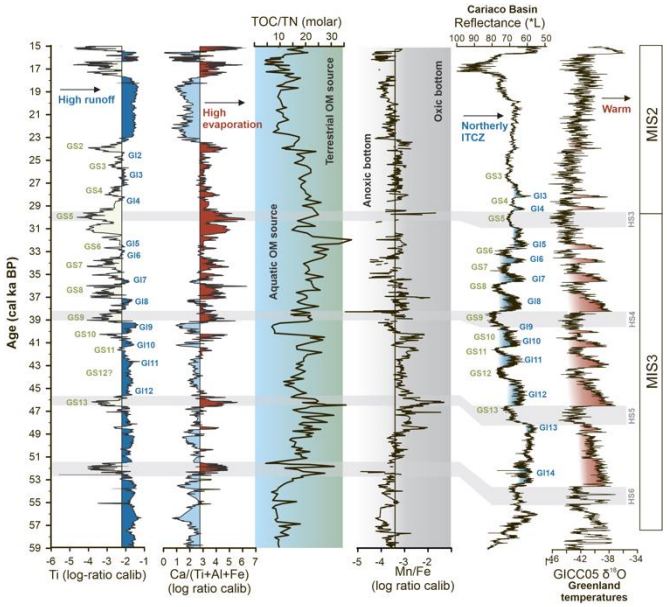

Figure 2: Comparison of proxy records of the PI-2 sequence between 59 to 15 cal ka BP. The timing for the transitions of MIS3-2 and the Last Glacial Maximum (LGM) are shown on the right. Runoff and evaporation are indicated by Ti values and Ca/Ti+Al+Fe log-ratios, respectively. Total organic carbon to total nitrogen (TOC/TN) ratios as indicators of organic matter sources, and Mn/Fe ratios as proxy for redox conditions. On the right we show the reflectance values (L) from the Cariaco Basin, lower values indicate a north migration of the Intertropical Convergence Zone (ITCZ). Moreover, oxygen isotopes (δ18O) from the GICC05 ice core record in Greenland are shown, less negative values are warmer intervals used to define Greenland Interstadials (GI).*

Results from Ti and Ca/(Ti+Al+Fe) ratios reveal a high variability in runoff and evaporation during MIS3 and the beginning of MIS2 (57-24 cal ka BP), respectively. However, a general trend to drier conditions inferred from

the increase of evaporation as shown by high values of Ca/(Ti+Al+Fe) ratios is observed after 39 cal ka BP. Simultaneously with the establishment of dry conditions, an increase in the total organic carbon/total nitrogen (TOC/TN) and Fe/Mn ratios suggests high terrestrial organic matter input and oxic bottom waters associated with low lake levels. During the Last Glacial Maximum (23-18 cal ka BP), the area was dominated by higher runoff causing lake level rise. A high variability in Ti and Ca/(Ti+Al+Fe) values, mainly between 50 and 23 cal ka BP, is associated with abrupt climate oscillations known as Greenland Interstadials (GI) and Greenland Stadials (GS). Our record indicates that GS were generally dry, particularly GS5, 7 and 8. Contrastingly, GI were characterized by more humid conditions, especially GI7-10. A regional comparison of changes in runoff in Petén Itzá with other records from the Caribbean, Central Mexico and the Gulf of Mexico suggests that the general tendency to dry conditions along MIS3-2 could be associated with the south migration of the Intertropical Convergence Zone (ITCZ), while wet conditions may be linked with the ITCZ northern position and the strength of the Atlantic Meridional Overturning Circulation that could increase the moisture transport to the northern Neotropics.

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IODP

Geochemical and magnetic indicators for tracing Quaternary glacial-interglacial water mass changes in the Gulf of Corinth (IODP Expedition 381)

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The Gulf of Corinth is a rapidly rifting basin that has been alternately connected to/isolated from the Mediterranean during the Quaternary due to glacio-eustatic sea levels fluctuations. New sediment records from the Gulf of Corinth (IODP Expedition 381) show repeated, drastic variations in magnetic susceptibility: Isolated intervals/glacial sediments are characterized by relatively higher and more variable values, while more stable values dominate in connected intervals/interglacial sediments. Using geochemical methods, we find that not the primary input of magnetic minerals, but diagenetic processes generated the magnetic susceptibility pattern (Mahoney and März, 2022). Easily reducible sulphides (most likely greigite) increase in high magnetic susceptibility (isolated/glacial) sediments, whilst magnetite shows no systematic relationship to magnetic susceptibility. After discounting several possible causes for greigite formation and preservation (bottom water redox conditions, high sedimentation rates, reactive Fe and organic matter availability), a decrease in sulphate concentrations in the Gulf of Corinth during isolated/glacial periods is the most likely explanation, supporting parallel microfossil evidence for repeated glacial freshening of the water column. This sulphate limitation appears to stall sedimentary pyrite formation at the stage of ferrimagnetic monosulphides like greigite. Greigite formation as an indicator of paleosalinity variations has been observed in other depositional settings (e.g., Chesapeake Bay, the Baltic Sea, the Miocene Paratethys and the Black Sea), supporting our interpretation. Specific to the Gulf of Corinth, linking a proxy for basin connectivity to a high resolution (at least 40, and up to 7 year temporal resolution) magnetic susceptibility record over 750,000 years offers an opportunity to investigate, in detail, the tectonic evolution of this rift basin and its link to global sea level fluctuations.

ICDP

ICDP Oman Drilling Project: Drilling through the crust mantle transition zone - the formation of massive dunites.

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The formation of oceanic crust at mid-ocean ridges is one of the dominant processes in the chemical differentiation of our planet. Oceanic crust formed at fast-spreading ridges exhibits a relatively uniform seismic stratigraphy and is regarded as layered and relatively homogeneous in mineralogy. Because of the lack of natural in-situ exposures at the base of the crust of recent oceans, existing models on the geodynamics of the deep processes during crustal accretion have never been tested directly using natural samples. Using the CM1 and CM2 drill cores penetrating the Oman ophiolite sequence, the best analogue for fast-spreading crust on land, recovered by the ICDP Oman Drilling Project, we started a study combining experimental work and investigations on samples of the drill cores in order to shed light on the nature of this the poorly understood crust-mantle transition. The drill cores CM1 and CM2 cover the upper mantle harzburgites at the bottom, followed by a 90 m thick massive dunite layer with layered gabbros at the top. Ni and Mg# in olivine as well as Cr#, Mg# and trace elements in chrome spinel were analyzed by EPMA and fs-LA-ICP-MS. The data reveals a homogeneous harzburgite composition, followed by homogeneous dunite in the lower part and an upper dunite section showing decreasing Mg#, and therefore more differentiated compositions towards the top. We conclude that only the upper half of the 90 m thick dunite has a cumulative origin. The lower dunite section may be formed as a result of reactions with harzburgite.

ICDP

Phases of stability during major hydroclimate change ending the Last Glacial in the Levant

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In hydroclimatically sensitive regions like the eastern Mediterranean, where water availability is a major factor for socioeconomic and political development, in-depth understanding of the reorganization of the hydrological cycle in response to global climate change is crucial. The Dead Sea and its drainage basin are the largest hydrological system in the Levant exceptionally located at the sharp transition from sub-humid Mediterranean to hyper-arid Saharo-Arabian climate. Past hydroclimatic changes in these climate zones resulted in large-scale lake level fluctuations and heterogeneous lacustrine sedimentation of the terminal lake system of the Dead Sea (Neugebauer et al., 2014; Torfstein et al., 2013). During the last glacial to Holocene transition (~24-11 kyr), the water level of Lake Lisan – the precursor of the Dead Sea – dropped remarkable ~240 m leading to its transition into the present hypersaline water body (e.g. Torfstein et al., 2013), which is recorded in the unique lake sediments.

Within the frame of the ICDP Dead Sea Deep Drilling Project, the unique sediment sequence of Site 5017-1 has been recovered from the deepest part of the Dead Sea Basin, spanning the last ~220 kyr in a 455 m long sediment record (Neugebauer et al., 2014). As part of the PALEX (Paleoclimate in the Eastern Mediterranean Region – Levant: Paleohydrology and Extreme Floods from the Dead Sea ICDP Core) project, we utilize high-resolution sedimentological analyses (microfacies and XRF) from this deep lake record in comparison to marginal terraces to reconstruct an unprecedented seasonal record of the last millennia of Lake Lisan.

During the major climate change at the end of the last glacial, we identified intercalated intervals of aragonite varves in our record showing that

(1) the stepwise long-term lake level decline was interrupted by almost one millennium of rising or stable water level, and that (2) even periods of pronounced water level drops as indicated by gypsum deposition (Torfstein et al., 2008) were interrupted by decades of positive water budgets. Further, even during periods of water level decline and generally instable lake levels, decadal-long varved sequences without any intercalated event layers indicate unexpected prolonged phases of depositional stability.

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IODP

Biological sulfate reduction in deep subseafloor sediment of Guaymas Basin

Toshiki Nagakura[1], Florian Schubert[1], Jens Kallmeyer[1] & IODP Exp. 385 Shipboard Scientific Party

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Sulfate reduction is the quantitatively most important anaerobic carbon mineralization process in marine sediment and has been studied extensively in many settings. Guaymas Basin, a young marginal ocean basin in the Gulf of California, Mexico is characterized by organic-rich sediment, high sedimentation rates, and high geothermal gradients (100-958°C km^{-1}) due to active seafloor spreading. We measured sulfate reduction rates (SRR) in samples recovered by International Ocean Discovery Program (IODP) Expedition 385 using $^{35}SO_4^{2-}$ radiotracer experiments carried out at in-situ pressure (~25 MPa) and temperature (4-77°C). Site U1548C is located just-outside of a circular hydrothermal mound (ringvent) and has the highest geothermal gradient (958°C km^{-1}) of all eight sampling sites. At the site, SRR were generally over an order of magnitude higher than at similar depths at other sites, we also measured the highest SRR (387 nmol cm^{-3} d^{-1}) of all samples from this expedition in near-surface sediment from this site. Sites U1545C and U1546D were located just 1 km apart and have very similar lithology, but Site U1546D had experienced a sill intrusion. The intrusion had already reached thermal equilibrium with the surrounding sediment and SRR were in the same range at both sites. The wide temperature range found in each of these drill cores leads to major shifts in microbial community composition with very different temperature optima. At the transition between the mesophilic and thermophilic range around 40 to 60°C, sulfate-reducing activity appears to be decreased, particularly in more oligotrophic settings but shows a slight recovery at higher temperatures.

IODP

Active versus arrested silica diagenetic front: Implications on the palaeoceanographic evolution across the Falkland/Malvinas Plateau

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A set of newly collected 2D seismic reflection data allowed for mapping two distinct cross-cutting reflectors across the Falkland/Malvinas Plateau (F/MP). Reflector XR-F/MB in the Falkland/Malvinas Basin is a Bottom Simulating Reflector which replicates the geometry of the present seafloor. Whereas reflector XR-F/MT in the Falkland/Malvinas Trough (F/MT) is a Non-Bottom Simulating Reflector which geometrically mimics a shallower reflector representing the Early-Middle Miocene unconformity. The discordant geometry of these two reflectors with respect to the host-stratigraphy implies that these are linked with post-depositional processes. Using the seismic characteristics, the origin of these two reflectors is investigated and is suggested to be associated with the Opal-A to Opal-CT conversion zone. Silica diagenesis is known to be primarily a function of temperature, however, the estimated temperature at the present depth for reflector XR-F/MB lies below the minimum temperature known for the onset of silica diagenesis. Seismic diagnostic features appoint these two reflectors as arrested silica diagenetic fronts. We discuss the viable scenarios that could account for the upward arrest of the diagenetic front in the F/MP. It is hypothesized that the erosional/non-depositional action of intensified deep and bottom water masses subsequent to the Antarctic glaciations during the Early-Middle Miocene may have triggered the arrest of the diagenetic front in the study area. Reconstructions suggest that a minimum of 270 meters of supposedly eroded overburden may make up for the minimum required thermal conditions for the initiation of silica diagenesis.

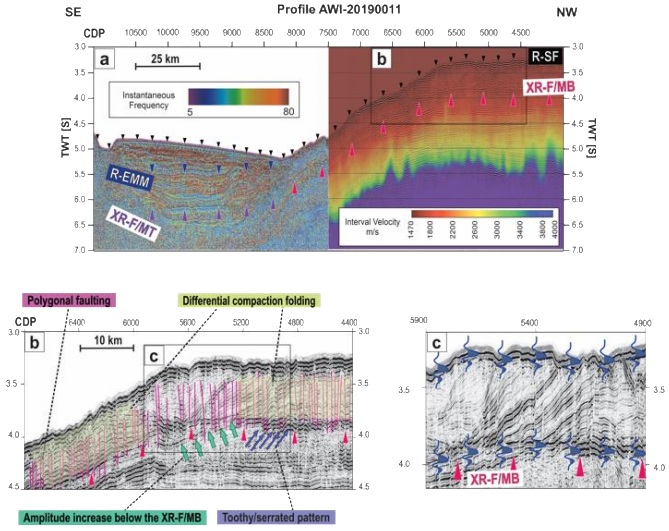

Figure 1: Seismic profile AWI-20190011. (a). Overlain on the seismic stack section are the seismic stacking velocity section on the right-hand side and the instantaneous frequency attribute on the left-hand side. (b) Zoomed section showing the peculiar structural features in the proximity of the cross-cutting reflector XR-F/MB. (c) Zoomed section showing the similar polarity of cross-cutting reflector XR-F/MB and seafloor reflection R-SF. The black and blue triangles respectively mark the seafloor reflection (R-SF) and the Early-Middle Miocene unconformity (R-EMM). The pink and purple triangles respectively mark the cross-cutting reflectors XR-F/MB and XR-F/MT. The black boxes mark the zoomed sections shown in (b) and (c).

ICDP

Results of the TEPH-ME project: Cryptotephras in the Lateglacial ICDP Dead Sea sediment record and their implications for chronology

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Tephrochronology has been demonstrated as a powerful tool for dating and synchronisation of palaeoclimate records for regional and global comparison (e.g., Lane et al. 2017). Due to a lack of visible tephra layers in the Dead Sea sediment record, direct links with the eastern Mediterranean tephrostratigraphical lattice have been absent so far. Recently however, the very first deposit of macroscopically invisible ash – cryptotephra – was identified in the Dead Sea sediments and has been associated with the early Holocene S1-tephra from central Anatolia (Neugebauer et al. 2017). This discovery encouraged a systematic search for cryptotephra time-markers in the ICDP Dead Sea deep-basin core 5017-1, with the aim of improving its chronology and providing a tool for precise synchronisation with other regional proxy records.

Here, we present results of the TEPH-ME project 'CryptoTEPHrochronology in the ICDP Dead Sea deep core as a key to synchronise past hydroclimate changes in the eastern Mediterranean', as a first outcome of the ongoing search for cryptotephras in the southern Levant. This study focusses on the Lateglacial (~15–11.4 cal. ka BP), when Lake Lisan – the precursor of the Dead Sea – shrank from its glacial highstand to the Holocene low levels.

We developed a glass shard separation protocol and counting procedure that is adapted to the extreme salinity and sediment recycling of the Dead Sea. Cryptotephra is abundant in the Dead Sea record (up to ~100 shards cm^{-3}), but often glasses are physically and/or chemically altered. In the studied Lateglacial time interval of the ICDP Dead Sea core, we have identified numerous cryptotephra horizons, from at least three different sources of Italian, Aegean and Anatolian volcanic centres. First glass geochemical data suggest that the majority of volcanic ash in the Dead Sea sediments originates from eruptions of the Anatolian volcanic provinces. Even though proximal Anatolian tephra data (glass shard analyses) for comparison are still limited, the identification of cryptotephra in the long Dead Sea record provides novel opportunities to advance the tephrostratigraphical framework in this region, e.g. not only through synchronizing the Dead Sea with the Lake Van (eastern Anatolia) sediment record, but also with archaeological and palaeoenvironmental sites that are currently investigated in the Levant and in Arabia.

Furthermore, the glass composition-based correlation of tephra populations in the Dead Sea with well-dated Lateglacial tephras of the Süphan and Nemrut volcanoes at Lake Van enabled us to improve the chronology of the Dead Sea record significantly, in a critical time window at the end of the last glacial improving our understanding of the hydroclimatic conditions in the region during abrupt climate changes (Müller et al., 2022). The results of this study pave the way for extending the tephra work at the Dead Sea, and for synchronization with other important palaeoclimate records in the Mediterranean region, like Lago Grande di Monticchio (Italy), Lake Ohrid (Albania/Macedonia), Tenaghi Philippon (Greece), and Lake Van (Turkey). The results have been published as Neugebauer et al. (2021).

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ICDP

Combined µEDXRF and LIBS analysis providing information on mineralogical and geochemical variation within magnetitite layers in the Upper Zone of the Bushveld Complex

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In the framework of the DFG-funded project "2D3DFusion: Development of fast 2D LIBS, EDXRF and Hyperspectral Imaging with application to outstanding problems of the Bushveld Complex layered intrusion" drill cores were obtained from the eastern limb of the Bushveld Igneous Complex. From these cores, about 14 m of magnetitite layers in the Upper Zone were sampled including the contact zone with the adjacent anorthosite and gabbronorite. The formation of these mono-mineralic layers is still being debated (Kruger and Latypov 2020) and the 2D data fusion of the applied methods on the meso- and micro-scale will provide more insight on the occurring processes.

The cores were mapped in 2D using Laser Induced Breakdown Spectroscopy (LIBS) and spatially resolved energy dispersive X-ray fluorescence spectrometry (µEDXRF). These methods provide a relatively fast overview of the element distribution along the drill cores, which is used for a subsequent mineral classification. The data processing is automated in an in-house software tool called Petrographic Analyst, which derives mineral distribution maps based on a spectral comparison with a mineral database using the supervised classification algorithm Spectral Angle Mapper. The database contains several thousand spectra of minerals from the Bushveld Complex, including a series of spectra for solid solution minerals, e.g. olivine, pyroxene or plagioclase. It was created using electron microprobe analyses and comprises additional information such as Mg#, Ca#, trace element concentrations and general sample information such as origin and location of the sample. All the additional information can be visualized as a colour code directly within the mineral maps. Adding the information from LIBS, which can measure almost all elements without the problematic Ti-V-Cr peak overlap in the EDX-spectra, provides information on vertical geochemical variations within the magnetite layers on a microscale (Figure 1). The data shows a general upward depletion of Cr and V in the massive magnetite, however, the V decrease is less pronounced. This trend is interrupted by several reversals near the anorthitic zones. The disseminated magnetite in the gabbronorite displays a much greater variability in composition. The continuous information of Cr, Ti, and V concentration in 2D combined with the mineral information along the drill core can provide detailed indications on the formation processes of these mono-mineralic layers.

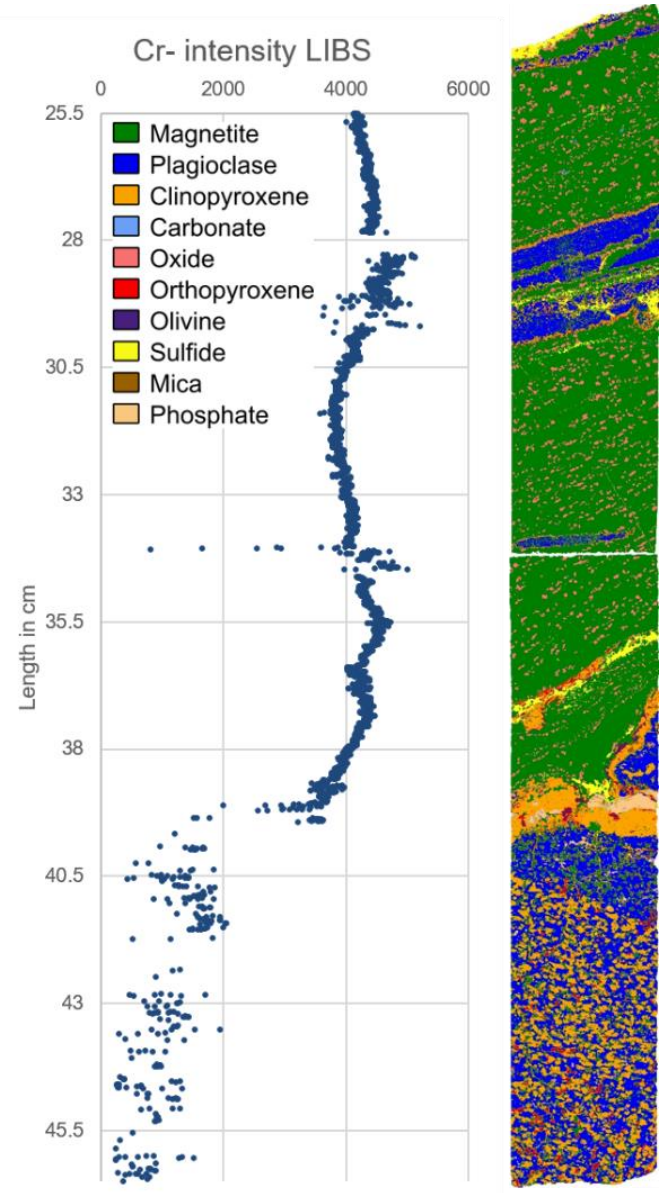

Figure 1: Mineral classification of a drill core section through a magnetite layer (right) with corresponding LIBS intensities (left).

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IODP

Preliminary syn and postglacial chronological information from a shelf-to-inland sediment core transect at the Eastern margin of the Laurentide Ice Sheet

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The Labrador Shelf, located in close proximity to regions where major parts of the ocean's deep water is formed, is a key area in the global thermohaline circulation. During deglaciations of the Laurentide Ice Sheet (LIS), large quantities of freshwater were released through Labrador fjord-trough systems into the Labrador Sea and the North Atlantic. These freshwater pulses had a major influence on the strength of the Atlantic meridional overturning circulation (AMOC). The AMOC, in turn, significantly influenced the climate of the Northern Hemisphere.

During *Maria S. Merian* expedition MSM84, sediment cores were taken from a transect across the former LIS margin. This comprises several cores from Lake Melville, a fjord-type inlet of the Labrador Coast, and cores on the Labrador shelf. At the end of the last glacial, the LIS retreated from the shelf towards inland, crossing the coring positions. The LIS reached the eastern end of Lake Melville at ca. 10 ka; the entire lake was ice-free at ca. 8 ka (King, 1985).

As a first step towards a robust chronology, radiocarbon dating was performed on 36 samples (mostly mollusk shells), 16 from the marine and 20 from the lake cores. Preliminary age modeling of the marine composite core MSM84-3CP exhibits a high-resolution record for the time span between ca. 8.3 and 11.5 ka cal BP (including the characteristic red layer that is attributed to the "8.2 ka event"), and erosion/non-deposition after 8.3 ka cal BP. The lake composite core MSM84-LMCP provides a continuous paleoclimate record from present back to ca. 10.5 ka cal BP. The lowermost part of the core is barren from mollusk shells and other carbonate fossils; hence, no chronological information is available from this part yet, but paleomagnetic analyses are in progress. It is likely that the basal age of this core is even older than 10.5 ka cal BP. At that time, the LIS still extended to the coastline or even onto the shelf and did not retreat to the coring location until ca. 9 ka. This implies that sedimentation took already place underneath the ice sheet. The Lake Melville composite core, therefore, could hold a paleoclimate record that reaches further back in time than the local deglaciation. The corresponding marine composite core allows to characterize the deglaciation in much detail, whereas postglacial paleoclimate evolution can be inferred from the lake record. This transect therefore offers the unique opportunity to perform a high-resolution study of the retreating LIS at the end of the last glacial.

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ICDP

ICDP-EGER pilot seismological 3D-array test site S2) installation, operational status and first observations

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One key element of the seismological monitoring concept within the ICDP-EGER project is the use of 3D-3C arrays for improving the detection and analysis of tiny swarm earthquakes. Using high frequency sensors and recording the wave field above the standard bandwidth of observations we aim to obtain a better understanding of the high-frequency wave-field radiated from the source region in Westbohemia/ Vogtland.

Here, we report on installation details and the status of the first 3D-3C array at the pilot test site S1 located in Landwuest (Saxony). Observations of two small swarm phases in December 2020 / January 2021 and April 2021 reveal the potential of the installation for detection and recording significant signal energy well above 100 Hz for the sensors at depth.

The detection capabilities of the array are compared with respect to bulletins published by WEBNET and SXNET. Additionally, we show results

obtained from the analysis of the high frequency wave field generated from the swarm earthquakes when estimating the full slowness vector at this new observational instrument. Not unexpectedly, local structures influence the recorded wave field at the 3D array as evidenced by converted waves inside the P coda and a loss of S wave coherence for specific event directions. However, we also observe an interesting azimuthal pattern of wave field distortion that can not be explained by local site effects only. Finally, the additional vertical slowness component that can be estimated with the 3D geometry of the array setting provides reasonable proxy-information on the focal depth for the analysed swarm earthquakes.

IODP

Tephrochronostratigraphy in marine 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, c. 250 km downwind (east) of the Taupō Volcanic Zone (TVZ), one of largest and most frequently active silicic centres on earth. The precursor volcanic arc, the Coromandel Volcanic Zone (CVZ), is a sparsely investigated Neogene volcanic arc, located NW of the TVZ.

The tephra inventories of the Exp. 375/372 cores provide the missing link between the proximal (onland, <100km) and distal (e.g. ODP Leg 181 cores, c. 1000 km) record, allowing the establishment of a near-complete eruption chronology from the early Miocene to recent.

Geochemical fingerprinting of the investigated marine tephras allows for a correlation between the proximal and distal sediment record, but also to onland deposits. Therefore, the total number of 1,005 marine tephras were investigated for their major element compositions (EPMA) and 419 tephras were analysed for their trace element compositions (LA-ICP-MS). 699 marine tephras are identified as primary tephras, of which 345 tephras are of the Quaternary whereas the other 354 tephras are of Miocene and Pliocene age. We identified 172 eruptive events during the Quaternary, of which 109 are correlated between holes, sites and to terrestrial tephra deposits (e.g. Taupō Tephra c. 1.7 ka; Kaukatea Tephra c. 860ka; Ototaka Tephra c. 1.6 Ma). 230 eruptive events occurred during the Miocene and Pliocene, of which 69 tephras were correlated between holes and sites.

Further investigations of the data will elaborate on multiple eruptions from the same eruptive centres, compositional variations with time, especially between the Coromandel and the Taupō volcanism, as well as frequencies and periodicities in the New Zealand tephra time series and their possible causes.

ICDP

Species diversity, sex ratio and body size of ostracodes in response to climate change in the northern Neotropics: the record from ancient Lake Petén Itzá, Guatemala

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Karst Lake Petén Itzá is a large (~100 km^2), deep (Z_{max}=165 m), closed-basin lake in the northern lowlands of Guatemala that possesses a continuous ~400-ka sediment record. Past conductivity and chemical composition of the lake waters were ideal for ostracode populations, making this taxonomic group a key paleoclimate proxy for inferring past water level, evaporation/precipitation ratio and temperature in this ancient lake.

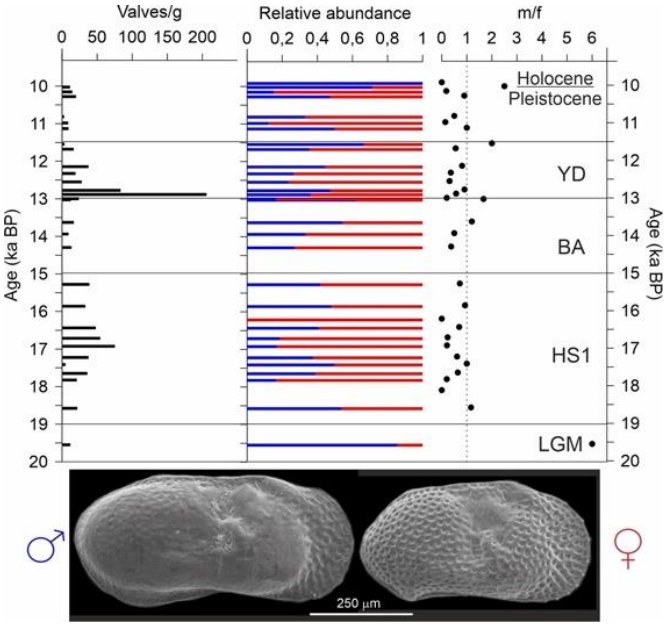

Figure 1: Total valves, relative abundance of males and females and sex ratio (m/f: males/females) of the endemic ostracode Paracythereis opesta in the PI-6 record from ancient Lake Petén Itzá during the LGM to the early Holocene (20-10 ka BP). Males are shown in blue, and females in red.

We used the ~80-ka ostracode record from ~75.9-m-long core PI-6 (water depth 71.0 m) to explore ostracode responses to abrupt climate and environmental changes, including Heinrich Stadials 6-1 (HS6-HS1). HS5-HS1 were dry and cold, as suggested by an abrupt decline in ostracode assemblage richness and diversity, whereas HS6 and HS5a were dry, but slightly warmer (Pérez et al. 2021).

Compared to other ancient lakes, ostracode species richness in Lake Petén Itzá has remained low (S=9), which we attribute to continuously fluctuating environmental conditions since the late Pleistocene, such as dramatic changes in water level and conductivity during the interval between HS6 and HS1. Dominant endemic species *Paracythereis opesta* and *Cypria petenensis* have, however, persisted in the lake, demonstrating great

resilience.

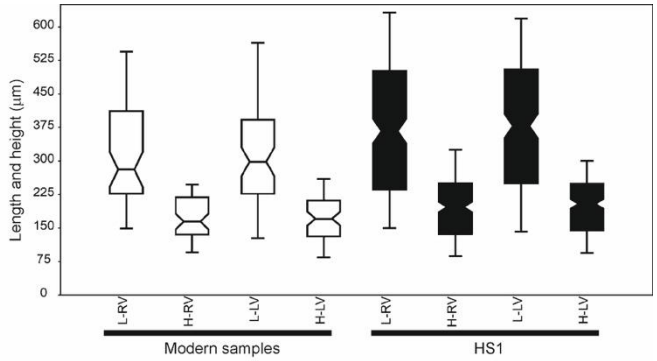

Figure 2: Boxplots of the length (L) and height (H) of measured right (RV) and left valves (LV) of modern surface sediment samples collected in years 2006 and 2008 (white boxplots), and sediment core samples corresponding to the Heinrich Stadial 1 (HS1, black boxplots). In the modern samples, 68 LV and 56 RV were measured, and 223 LV and 232 RV in the HS1 samples.

Few long sediment records have been used to explore the effects of past climate change on the reproductive strategies and body size of ostracodes. With this in mind, we investigated the sex ratio (Fig. 1) and valve size (length and height, Fig. 2) of *Paracythereis opesta* over the last ~20 ka. Results indicate: (1) a reduction in body size over time, which we attribute to higher temperatures and fresher lake water conditions, (2) female dominance during dry and stable conditions, with males appearing mostly during wetter periods and higher water levels, such as the Last Glacial Maximum (~23-19 ka) and warm Early Holocene (~9.8 ka BP), and (3) sexual dimorphism, which is already apparent in the last larval stage.

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IODP

New Late Miocene climate records raise questions about the traditional narratives of Coral loss and development in the Coral Sea

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The Queensland Plateau in the Coral Sea has one of the best-constrained geologic histories of coral reef expansion and demise since the early Miocene. However, despite this well-established record, many traditional climatic causes for the development and loss of coral reefs are based on very little climate data or outdated records. Therefore, the development of coral reefs in the past is not well understood, given their predicted vulnerability to future climate change. Coral reefs were first established in the Early Miocene in the Coral Sea. In the Late Miocene, between 11 and 7 Ma, the reef area on the Queensland Plateau declined by ~50% leading to a partial drowning and a change in platform geometry from a reef-rimmed platform to a carbonate ramp. The loss of the reefs has often been tied to the expansion of cool, nutrient-rich waters in the Coral Sea during the Late Miocene. This model has been used to explain the loss and development of corals in other parts of the globe. However, there have been questions about the planktonic $\delta^{18}O$ based Sea Surface Temperature (SST) records and facies analyses on which the cool nutrient-rich water theory is based and how accurately they reflect changing SSTs. Here we show new TEX_{86} SST data from the Queensland Plateau from ODP site 811/825 for Late Miocene. Our data shows that instead of cooler SSTs during the Late Miocene, SSTs were warmer than in the modern Coral Sea and at the upper end of the contemporary coral growth window during the period of coral reef loss. There is also evidence of increased nutrient availability during this time as well. Our record suggests that while changes in SST play a role in coral reef loss and expansion, SSTs alone did not act as the cause of coral reef loss. Instead, we think that instead of cold, nutrient-rich waters affecting the site during the Late Miocene, warm water-adapted corals were impacted by changing climate, sea level, and nutrient availability during climatic changes during the Late Miocene. Therefore, this shows that although corals can adapt to warmer SSTs, this happened in radically different oceanographic conditions and that the coral reefs that developed were vulnerable to changing climates. This raises red flags for the ability of coral reefs to adapt to future climate change.

ICDP

Cyclostratigraphic studies of Lake Junín (Peru) sediments from downhole logging and core data to investigate paleoclimatic implications

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Lake sediments register environment and climate changes over time. The response of depositional environments to climatic variations is often quasi-periodic in time, and these climatic (glacial/interglacial, or insolation-paced) variations are often embedded in sediments and recognized as variation in their physical and chemical properties (e.g. grain size, mineral type, mineral abundance especially for clay, organic matter). These properties can commonly be detected in cores and also by downhole logging measurements. Here, we present a cyclostratigraphic studies based on combination of downhole logging data and selected core samples from the ICDP Lake Junín drilling project.

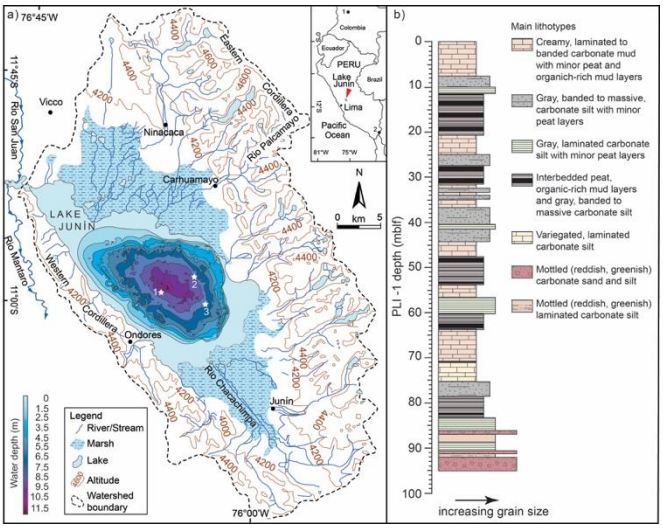

Figure 1: (a) Lake Junín, its drainage basin and bathymetry. The white stars indicate the three drill sites. (b) Stratigraphic column of the core PLJ-1 splice at the Site 1.

Lake Junín, a 300 km^2 semi-closed shallow basin situated 4085 m above sea level in the northern-eastern part of the Peruvian Andes, is characterized by a thick heterogeneous sediment package deposited at a high rate (0.2-10 mm yr-1). It is one of the few lakes in the tropical Andes that predates the maximum extent of glaciation, although the paleo-glaciers reached only the lake edge without overriding the lake in as much as a million years. The main goal of the ICDP Lake Junín drilling project was to obtain high-resolution

paleoclimate records from lacustrine core sediments to reconstruct the history of the continental records covering several glacial-interglacial cycles. The present study aims to reconstructing paleoclimatic records as well, including estimating lake sedimentation rates, identifying glacial-interglacial climate variations, and building the age depth model using only borehole record data and selected core samples.

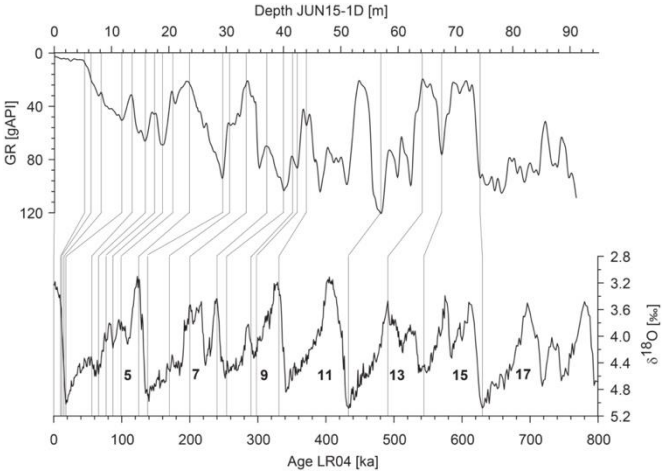

Figure 2: Correlation of the GR data of Hole JUN15-1D (top) to the LR04 stack (bottom). Grey lines indicate correlation tie points. Numbers in the d18O record represent Marine Isotope Stages (MIS).

The first step of our study was to use the natural and spectral gamma ray logging data for cyclostratigraphic analysis, and to apply the astronomical spectral misfit method (ASM) to reconstruct the sedimentation rate, the results of which indicate a sedimentation rate of between 5 and 20 cm/kyr. Then, the TimeOpt method was applied to test for a fit of precession amplitude with eccentricity resulting in an average sedimentation rate of 15 cm/kyr. Based on these results the gamma ray data were also correlated with the LR04 benthic isotope stack, which identified 16 glacial-interglacial cycles. The second step was to analyze the downhole logging data for petrophysical properties and cluster analysis to construct a lithology profile and assign lithology at core gaps. The properties of the clusters were analyzed and converted into lithological units based on the lithological information obtained from the visual description of the core or the mineralogical analysis of the core material. Changes in mineralogy and especially clay mineralogy were interpreted and associated with glacial/interglacial periods. Mineralogical analyses performed by X-ray diffraction (XRD) show different contents in quartz, calcite, feldspar, and clay minerals, the latter contains illite, smectite and kaolinite in varying amounts. By linking the abundance and lack of clay minerals in the core samples with depth logging data, it was possible to recognize a relationship between the geological history of the lake and climate change processes. In addition, the different mineralogical composition of the sediments, especially the presence or absence of smectite in the clay mass, reflects glacial/interglacial climate cyclicity. Combining borehole logging and mineralogical data, it was observed that their variation at depth are related to climate changes, which influenced the sedimentation of Lake Junín, over the past 700,000 years.

ICDP

3D imaging of the subsurface electrical resistivity structure in West Bohemia/Upper Palatinate covering mofettes and Quaternary volcanic structures by using Magnetotellurics

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The region of West Bohemia and Upper Palatinate belongs to the West Bohemian Massif. The study area is situated at the junction of three different Variscan tectonic units and hosts the ENE-WSW trending Ohře Rift as well as many different fault systems. The entire region is characterized by ongoing magmatic processes in the intracontinental lithospheric mantle expressed by a series of phenomena, including e.g. the occurrence of repeated earthquake swarms and massive degassing of mantle derived CO2 in form of mineral springs and mofettes. Ongoing active tectonics is mainly manifested by Cenozoic volcanism represented by different Quaternary volcanic structures. All these phenomena make the Ohře Rift a unique target area for European intra-continental geoscientific research. Therefore, 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 were applied to image the subsurface distribution of the electrical conductivity from shallow surface down to depths of several tens of kilometres and to map possible fluid pathways. 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. Within three field experiments from 2015 to 2018 different targets within the Eger Rift were covered. 2D inversion results (Muñoz et al., 2018) reveal a conductive channel in the vicinity of the earthquake swarm region that extends from the lower crust to the surface forming a pathway for fluids into the region of the mofettes. Only 3D station coverages and inversion models allowed to locate this channel next to the hypocentres of the earthquake swarms (Platz et al., 2022), similarly to what was observed at the San Andreas fault (Becken et al., 2011). This 3D inversion result images prominently different fluid/magma reservoirs at lower crustal depth with their fluid pathways to the surface feeding known mofette fields and the two spas Františkovy Lázně (FL) and Mariánské Lázně (ML). Dense MT arrays together with high frequency (=> shallow) Radio-Magnetotelluric (RMT) measurements helped mapping possible CO2 migration paths within the Cheb Basin into the mofette fields. Some of the Quaternary maars in the area were also crossed with several RMT profiles allowing to map the deeper cores and to derive the sedimentation history. Contrary to the other targets a deep feeder channel could not be identified.

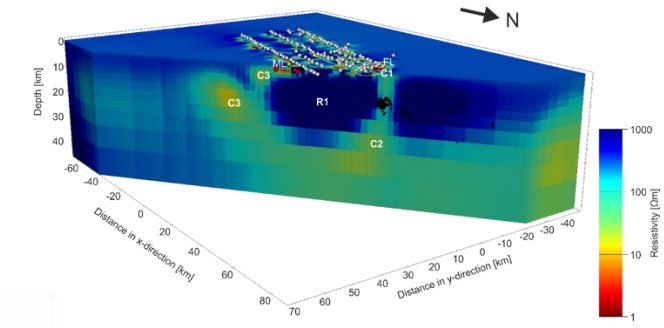

Figure 1: Southeast-northwest cut through the 3D model from Platz et al. (2022) along the imaginary connecting line between the two spas Františkovy Lázně (FL) and Mariánské Lázně (ML). Large parts of the model are dominated the crystalline basement (blue colours). Several conductive structures (yellow and green colours) interrupt the basement representing possible pathways for ascending fluids and gas.

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IODP

Unraveling interplay of magmatism, tectonics, and mass-wasting at the Christiana-Santorini-Kolumbo volcanic field: outlook on core-log seismic integration on the upcoming IODP Expedition 398

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The Christiana-Santorini-Kolumbo (CSK) volcanic field in the southern Aegean Sea is one of the most hazardous volcano-tectonic regions in the world, posing a major threat to the eastern Mediterranean. Here, not only Europe's strongest 20th-century shallow earthquake occurred (M7.4 in 1956), but also the iconic Minoan eruption 1650 BCE which is thought to have contributed to the fall of the great Minoan civilization. Extensive research in recent decades has led to a robust stratigraphy of onshore Santorini volcanism for the past ~650,000 years and revealed the internal architecture of the adjacent rift system as well as the relative chronological evolution of different volcanic centers. However, since most of the volcano-sedimentary sequences are hidden beneath the seabed, major observation gaps regarding the volcano-tectonic evolution of the CSK field remain. To address these uncertainties, IODP Expedition 398 is scheduled to drill six sites along the CSK volcanic field. We propose to conduct core-log seismic integration at all six drill sites to address four of the five primary goals of this IODP expedition. By extending the constrained 1D stratigraphic model from the drill sites regionally throughout the rift basins and the caldera using our extensive collection of seismic lines, we will be able to constrain sources, distributions, and volumes of individual volcano-sedimentary units. From that, we will answer fundamental questions regarding the ages, volumes and nature of volcanic eruptions from the adjacent Christiana and Kolumbo volcanoes, the nature of deposits within Santorini Caldera, the volume of the Minoan eruption products, and the relationship between rift pulses and volcanic eruptions. This will allow us to better understand the dynamics of disaster cascades, in which tectonic unrest, volcanic eruptions and mass-wasting closely interact. Understanding these interwoven processes is crucial for a more reliable risk assessment for this area of high socio-economic importance.

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IODP

CODO – Coupling of deep-sea pH, ocean circulation and climate during the Cretaceous/Paleogene transition

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The oceans are not only a sink for the heat produced by the greenhouse effect, but also for carbon dioxide (CO_2). Therefore, the oceans play a crucial role in shaping Earth's climate system. Global climate was characterised by severe changes in global temperature between the two greenhouse climates of the Cretaceous and the Eocene. These long-term changes in global climate have previously been linked to changes in sink and sources of CO_2 such as volcanism and tectonic processes, but in as much the deep-sea reflects changes in the global carbon cycle, remain unclear.

The work proposed here will address this issue by constraining the role of the deep-sea carbon cycle in controlling climate from both a long-term and a short-term perspective, focusing on the Late Cretaceous to Paleogene and K/Pg boundary. To achieve this, we will use boron isotopes in benthic foraminifera from various IODP, ODP and DSDP sites in the North and South Atlantic in order to constrain deep-sea carbon cycle changes from 72 to 55 Ma. The main research questions are:

Are late Cretaceous and early Paleogene long and short climatic changes reflected in the deep-sea carbon reservoir? To what extent did deep-sea pH change in response to the K/Pg impact event? Together, these results have the potential to fundamentally improve our understanding on how the deep-sea takes parts in the global carbon cycle during periods of climatic and oceanographic change.

ICDP

Mesoscale investigation on drill cores. The key to keep track of macro to micro relationships.

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A number of spectral imaging methods such as LIBS (Laser Induced Breakdown Spectroscopy), µEDXRF (spatially resolved Energy Dispersive X-Ray Fluorescence spectroscopy with down to 20 µm resolution), and hyperspectral imaging (HSI: VNIR, SWIR and LWIR) provide textural, mineralogical, and chemical information at the mesoscale[2]. Since the methods are easy to apply and fast, many sample sections and even drill cores can be measured continuously for several meters, linking macroscopic information to microscopic details, providing objective measures for detailed sampling for subsequent detailed micro analytical analyses while keeping the relation to the neighbourhood. These imaging methods are sensitive for a large number of geological questions, such as cryptic layering in magmatic rocks, metamorphic or metasomatic overprint, micro tectonic impact, deformation, characterization of individual fragments of conglomerates, fine lamination in sediments, identification of high tides and tsunami depositions, and detection of accessory minerals to identify potential resources.

Mineral classification of HSI, LIBS, and µEDXRF imaging data, however, requires an extensive mineral database to allow on the one hand the characteriation of individual fine-grained layers and on the other hand the characterisation of coarser phases and especially individual members of solid solutions, such as plagioclase or amphiboles. The database has to be optimized for individual questions to focus on the relevant endmembers needed to avoid misinterpretation. Based on diagnostic endmembers or specific spectral features, a relative objective way is provided for the characterization of core sequences according to mineralogy and/or chemistry. Pixel co-registration and data fusion will enhance the information level dramatically since none of the applied methods is able to provide all the necessary information. Merged chemical and mineralogical pixel-based information of the individual methods provides a new dimension for sample interpretation, which is especially of interest for mineralization, alteration, rock nomenclature, cryptic layering, textural features such as lamination, veining, grain size etc. To reach so far, a number of obstacles obstructing

interpretation have to be removed, but even disturbing information such as µEDXRF related diffraction signals can be used to obtain better information of grain size distribution, focusing on mono-mineralic aggregates or even on deformation in chromitites and dunites from ophiolite complexes.

A few examples are shown to demonstrate the gain of knowledge with the application of HSI, LIBS, and µEDXRF scanning technologies. Continuous scanning with LIBS of a 6 m drill core from the Merensky reef, Bushveld Complex, South Africa, has shown the cryptic variation of chemical patterns of individual minerals highlighting changes in the anorthite content of plagioclase and Mg/(Mg+Fe) in pyroxenes, olivines and spinel in relation to the phase modality consistent with EPMA data[3]. In another sample from Lake Constance, finely laminated sediments representing seasonal changes with intercalated high tide events from the Rhine disturbed by succeeding Bregenzer Ache input can be differentiated. Finally, highly deformed chromitites from the deep tectonite level of the central Palawan Ophiolite, Philippines demonstrate the potential of diffraction signals as a by-product to differentiate chromitite occurrences.

ICDP

Local noise sources retrieved from seismic double cross-correlations: A feasibility study in the region of Landwüst (Germany)

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The ICDP project “Drilling the Eger Rift“ focuses on the investigation of geodynamic processes in W-Bohemia (Czech Republic) and Vogtland (Germany), such as earthquake swarms and degassing of CO2 originating from the Earth’s mantle. In order to get new insight into the dynamics of these processes, three boreholes were drilled in this region and will be used to install high-frequency 3D seismic arrays. The pilot 3D array is located 1.5 km south of Landwüst (Vogtland, Germany). In the test phase the borehole with a depth of 402 m was equipped with a vertical array of 8 geophones (now changed to 10) with a corner frequency of 10 Hz. The borehole chain is complemented by a 400 m aperture seismic surface array of 12 4.5 Hz geophones. The continuous data of the 3D seismic array with a sampling rate of up to 1000 Hz are integrated into the ICDP-Eger virtual network.

In this study, we aim to investigate whether weak continuous noise sources, such as those that can arise from the movement of fluids through narrow fractures near the surface, can be detected and localized. For this purpose, we have developed a new approach to localize such tremor sources using a seismic array in combination with a regional seismic network. It is based on a double cross-correlation between a real data cross-correlation in selected windows and cross-correlations of synthetic data for a 3D grid of point sources with variable mechanisms. The most probable source position is the grid node with the highest zero time lag amplitude of the double cross-correlations of each station pair.

We evaluate the location accuracy from synthetic deep tremor signals calculated for different source positions and source mechanisms (e.g., double couples, tensile opening cracks and compensated linear vector dipoles) in a 1D stratified Earth model. We test the sensitivity of the location approach for known and unknown source mechanism. Our synthetic tests indicate an accurate location of continuous tremor sources to depths of up to 7 km.

IODP

800 000 years of millennial-scale variability in the Southeast Pacific

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The Antarctic Circumpolar Current (ACC) is the world’s strongest current connecting the Atlantic, Pacific, and Indian Ocean basins, and also linking the deep and shallow layers of the ocean [1]. The major constriction of the ACC is the Drake Passage (DP), connecting Pacific and Atlantic. The DP throughflow, also called the “Cold-Water route”, exerts a strong control on the Atlantic Meridional Oceanic circulation. However, little is known concerning glacial-interglacial variations in the export of water masses in the DP. It have been argued that most of the northern ACC is exported northward to the South Pacific gyre during glacial periods while during warmer time a greater part of northern ACC would be deflected to the Atlantic Ocean via Drake Passage [2]. Resolving changes in the flow of circumpolar water masses through this gateway over glacial and interglacial cycles is, therefore, crucial for advancing our understanding of the Southern Ocean’s role in global ocean and climate variability. In the perspective to assess changes in the flow of circumpolar water masses through Drake Passage, we reconstructed over the past 800 kyr an unprecedented millennial scale resolution from drill Site U1542 located at ~1100 m water depth, where a complete composite sediment record has been recovered during IODP Expedition 383. Site U1542 is in the northern ACC system close to the Chilean Margin linked to the Southern Ocean through the Drake Passage throughflow [3]. We performed alkenones-derived Sea Surface Temperature (SST) reconstruction at ~700 yr interval during cold period to explore in detail the orbital and sub-orbital-scale climate variability in the subantarctic ACC and compare Antarctic ice core record. Alkenone-based SST at Site U1542 documents variability about ~9 °C between glacial and interglacial periods and mainly eccentricity driven. Superimposed to this orbital variability, we observe high amplitude SST variations (~2-3°C) at millennial scale, stronger than Antarctic ice core during glacial which infer a decoupling between mid and high southern latitudes, potentially due to enhanced circum-Antarctic circulation [4]. Additionally, synchronous variations between alkenone-derived SST and Zr/Rb ratio, demonstrated to be representative of bottom sea current variations [5], suggests a tight coupling between deep and shallow water. This study provides insight into disentangling role of the ACC in ocean circulation at millennial scale, more precisely changes in the transfer between oceanic basins. Our next step is to explore zonal and latitudinal gradients during glacial/interglacial periods by comparing between Site U1542 with similar time-scale record in both Pacific and Atlantic.

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IODP

An open access platform to document and retrieve composite records from ocean drilling sites - the Ocean Drilling Composite Tracker (ODCT)

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A key concept in scientific ocean drilling in order to recover continuous multi-million year spanning successions from the sea floor is the formation of composite records. Drilling multiple holes at a given site and the subsequent assemblage of an undisturbed and complete sediment sequence allows scientist to retrieve outstanding, several hundreds of meters thick records for paleoclimate reconstructions. Fifty years of ocean drilling clearly revealed that a single drilled hole is not adequate to be able to resolve the progression of climate change needed to identify causal mechanism. The composite records from multiple drilled holes have become the backbone of paleoceanographic research to better understand Earth past climate changes. Typically during a two month-long ODP/IODP Expedition targeting to retrieve full sediment successions from the sea floor a composite is formed routinely onboard by the Stratigraphic Correlator. The quality of the composite record depends mainly on the careful correlation of prominent features in the core, which in turn depends on the quality of the data used for correlation. In addition, to evaluate, verify and improve shipboard composite records other more time consuming techniques with higher signal-to-noise-ratio help to substantially revised composite records, and sometime reveal major gaps or repeated interval in composite records. Thus, years after an expedition checks and revisions can result in an iteratively evolving composite with multiple published versions.

Here we present a new project to develop an open access and cross-platform software tool to document and track all of the published and future composite records of scientific ocean drilling core sites, the Ocean Drilling Composite Tracker. Scientist can use this tool to generate sample lists with sample identification as well as composite depth and vice versa for different composite versions, retrieve alternative sample locations in parallel sections that are not part of the composite record, extract data according to the composite from the drill core database, and retrieve ages for the samples or data using published age models. This tool is one step towards applying machine-aided data analysis and extraction.

IODP

A new perspective on the MECO 'Carbon Cycle Conundrum': d30Si records from the South Pacific

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The silicate weathering feedback is a key factor in stabilizing atmospheric carbon dioxide on geological timescales. It has been increasingly recognized that it moderates the climate over tectonic timescales. However, the potential of variable operation of the feedback over shorter timescales is not yet fully understood. A recent interpretation of the the weathering-sensitive isotope system $^{187}Os/^{188}O$ suggested weakening of the feedback over a 500 kyr global warming period known as the Middle Eocene Climate Optimum (MECO) (van der Ploeg et al. 2018). However, a feasible driver for any such transient weakening, and for subsequent reinvigoration of the feedback during MECO cooling, is unclear. Here, we interrogate the idea of a weakened silicate weathering feedback as a driver of the MECO using high-resolution Si isotope measurements from planktic radiolarians and benthic sponge spicules, measured via multicollector inductively-coupled plasma mass spectrometry (MC-ICP-MS). By combining these two archives, we can glean information about global weathering intensity and paleo circulation (e.g. Fontorbe et al. 2016, 2017).

We present new data from spumellarians and nassellarian radiolarians – together with co-eval bottom-water sponges – from the South Pacific (IODP Site 1511) across the MECO. We add to the increasing body of evidence showing that Si isotope fractionation in radiolarians is species-specific. We discuss these data with reference to previous measurements of Eocene radiolarian $\delta^{30}Si$ (e.g., Fontorbe et al. 2016, 2017) and weathering-sensitive isotope ratios (e.g., van der Ploeg et al. 2018), and in terms of their implications for silicate weathering feedback strength, ocean circulation, and the marine silicon cycle.

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IODP

Water mass provenance in the Atlantic Sector of the Southern Ocean during the past 500 ka revealed by neodymium isotopes

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The Southern Ocean (SO) is of major significance for the understanding of the ocean´s impact on Earth's climate as uptake and release of CO_2 strongly depend on the redistribution of well and poorly ventilated water masses.

Neodymium isotopes preserved in deep sea sediments have proven useful to study the deep ocean circulation and water mass provenance thanks to basin scale isotope gradients between the Pacific and the North Atlantic.

Here we present novel Nd isotope data (ε_{Nd}) of the sediment cores ODP 1094 in 2.8 km and ODP 1093 in 3.6 km water depth in the Atlantic sector of the SO south of the modern polar frontal zone. The ε_{Nd} records over the past 500 ka include several glacial-interglacial cycles indicated by systematic temporal changes in a range of 6.3 ε-units in ODP 1093. Concentration measurements of the other leached elements including REE reveal that the ε_{Nd} variability of the deeper situated core is driven by glacial-interglacial changes in ocean circulation, whereas the shallower drilling site is likely influenced by a local interference of radiogenic Nd, resulting in highly variable ε_{Nd} values.

During peak glacial periods of MIS 2, 6 and 12 with maximum sea ice extent and a shoaled AMOC we observe radiogenic ε_{Nd} values of -2.5 to -3.5. This confirms a predominance of glacial PDW at depths of >3 km with proportions close to 100% and thus increasing the water volume portion with enhanced respired carbon.

The ability of ε_{Nd} to trace water mass changes largely depends on the sensitivity of water masses to Nd isotope mixing. Studying the gradient ($\Delta\varepsilon_{Nd}$) over the Atlantic through ODP 1093 and ODP 1063 allows for a broader understanding of water mass provenance and thus AMOC flow strength.

Hence, our results enforce the leading role of the SO in storing and reinjecting respired CO_2 into the deep Atlantic Ocean and the atmosphere during glacial-interglacial terminations and draw a broader picture on AMOC strength variability.

ICDP

Selective metabolic traits of the subsurface biosphere in the 1Ma ferruginous archive of Lake Towuti

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Lake Towuti (2.5ºS, 121ºE), Sulawesi Island, Indonesia, is a tropical tectonic lake surrounded by ultramafic rocks and lateritic soils (Haffner et al., 2001). With a maximum depth of 203 m, it is weakly thermally stratified (31ºC-28ºC), and even though it is currently anoxic below 130m, it has been inferred to mix periodically leading to short-term oxygenation of its bottom waters on a geologic timescale (Costa et al., 2015). Due to its ferruginous conditions (iron-rich, sulfate-poor) and low productivity as the abundant iron oxides scavenge phosphorus, it is considered to be a suitable modern analog for Archean and Proterozoic oceans (Bauer et al., 2019; Friese et al., 2021). Thus, the study of the active, modern biosphere in Lake Towuti could help understand crucial metabolic processes that functioned in the Earth's early ferruginous oceans (Friese et al., 2021).

Within the scope of the International Continental scientific Drilling Program (ICDP), the Towuti Drilling Project (TDP) recovered a 100m-long core from 156m water depth dedicated to geomicrobiology in 2015. To check for contamination of the drill core by drilling fluid, a tracer applied to allow for identification of uncontaminated core sections (Friese et al., 2017) that were then sampled for molecular analysis.

As part of a recently started DFG-funded research project sequencing data from sedimentary DNA will be integrated with results from geochemistry and paleoecology studies to fully understand the relationship between the microbial ecosystem and depositional changes that occurred in Lake Towuti in response to climatic variation (Russell et al., 2020). Metagenomic sequencing data will be produced to identify and quantify microbial taxa and their metabolic traits involved in biogeochemical processes that alter the sediment substrates (e.g. Fe mineralization, remineralization to methane).

Available geochemical and biological data show that the pore water experiences a drastic depletion in electron acceptors in the upper 0.4 meters below lake floor (mblf), continuing a trend that has already started in the stratified, ferruginous water column. This translates into a 4 orders of magnitude drop in cell counts and a reorganization of the microbial metabolic guilds, which transition from a sulfate-reducing to a fermentative assembly driving organic matter remineralization to methane (Vuillemin et al., 2018). Sulfate reduction rates rapidly decrease within the upper 0.2 mblf but remain detectable down to 10 mblf (Friese et al., 2021). Some related functional marker genes found to be abundant in metagenomes are indicative of respiration of sulfite, elemental sulfur and polysulfide. In the next meters below the SMTZ, cell densities remain fairly constant, with a taxonomic diversity predominantly composed of Bathyarchaeia. The main functional marker genes in this horizon relate to the methanogenic Wood-Ljungdahl pathway with fermentation of volatile fatty acids. Bathyarchaeia have metabolic potential to participate in all these pathways, which could explain their increased presence at the SMTZ and into the fermentative zone.

Our current objectives are to produce metagenomic data from the surface down to 100m depth to cover 1Ma of lacustrine history (Russell et al., 2020; Vuillemin et al., 2022) and present the first complete characterization of the lacustrine subsurface biosphere in terms of diversity, abundance and metabolic functions. We aim to determine which environmental parameters exert selection on microbial communities and which functional genes allow specific microbial elements to actively persist in the subsurface under ferruginous conditions (i.e. limitation in organic substrates and respiratory electron acceptors). Finally by reconstructing their sulfur metabolism and Wood-Ljungdahl pathway, which is considered to be the first metabolism for energy generation and carbon fixation in Archaea (Borrel et al., 2016), we will investigate the role of Bathyarchaeia in this system to provide a model of biogeochemical processes that likely operated in ferruginous deposits of the early Earth.

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IODP

Sea surface temperature and productivity records from the Pacific Southern Ocean spanning the last 5 million years

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To explore the largely unknown Cenozoic paleoceanography of the Pacific Southern Ocean, we generate proxy records from Site U1541 that was drilled during IODP Expedition 383 and is located ~180 km north of the modern Subantarctic Front in the central South Pacific. We analyze alkenones

and total organic carbon (TOC) content at Site U1541 and derive sea surface temperature (SST) and phytoplankton productivity records now spanning the last ~5 My. Pliocene average SST at Site U1541 were ~10°C and thus ~4°C warmer than modern and Pleistocene average values, suggesting a southward shift of the Subantarctic Front and a more extensive/warmed Pacific subtropical gyre. Our record indicates initial cooling of the subantarctic Pacific at 2.5–3 Ma, with the underlying oceanographic reorganization potentially being linked with the intensification of the cold upwelling tongue in the tropical East Pacific (1). The Pleistocene is marked by glacial/interglacial SST changes of up to 6–8°C suggesting major northward/southward shifts of the Subantarctic Front over Site U1541, which are most pronounced after the Mid-Pleistocene Transition (MPT). The alkenone and TOC concentrations indicate that the phytoplankton productivity in the subantarctic South Pacific was enhanced during glacials and reduced during interglacials, a pattern that emerged during the MPT. This is similar to findings from the subantarctic South Atlantic and consistent with the idea that the glacial subantarctic phytoplankton productivity was stimulated by dust derived iron fertilization and contributed to lowered atmospheric CO_2 (2). Our emerging new proxy records will provide unprecedented insights into southern high-latitude ocean–atmosphere–cryosphere dynamics and their implications for regional and global climate and atmospheric CO_2 during warmer than present times and glacial/interglacial cycles.

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ICDP

Detecting tephra layers across the lacustrine deposits of Lake Chalco, using high-resolution gamma ray spectrometry

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Lacustrine sediments are archives of past environmental conditions. In recent decades, multinational ICDP efforts have conducted lake drilling projects to encode the potential of paleoclimate signals. Gamma-ray spectroscopy is a particularly useful tool as it is non-destructive, fast, and affordable even in cased boreholes. Gamma radiation can be used to identify elemental isotopes in the geological record, which is used for stratigraphic correlation and paleoclimatic investigations.

However, some lake sediments contain tephra layers with specific gamma-ray signatures, presenting a challenge for extracting the primary signals caused by environmental and climatic agents (Sardar Abadi et al., 2022). Here, we use the sediments of Lake Chalco in central Mexico to propose a protocol to identify tephra layers embedded in other sediments using high-resolution spectral gamma-ray spectroscopy. This facilitates dividing the overall sediment column into representative horizons of tephra and non-tephra.

Among the upper 300 m of the lake deposit, our index detected 363 tephra layers, while 388 total tephra layers (≥1 mm in thickness) were reported from the core description of the same borehole, predicting 92% of tephra layers documented in the lake deposits from core descriptions. We suggest that not only the strength of the gamma-ray signal, but also the composition of its constituent energy channels can be used to detect embedded tephra layers.

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ICDP

Pleistocene climate variability in eastern Africa influenced hominin evolution and dispersal: results from the Chew Bahir record

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The regional environmental context of hominin evolution and dispersal is still a matter of debate, mainly due to the lack of continuous paleoenvironmental records from the habitats of early human populations in Africa. The 620,000-year environmental record from Chew Bahir, southern Ethiopia, which is proximal to fossil key sites as Omo Kibish and Herto, documents the potential influence of different episodes of climatic variability on hominin biological and cultural transformation. The appearance of high anatomical diversity in hominin groups coincides with long-lasting and relatively stable humid conditions from ~620,000–275,000 years BP, interrupted by several abrupt and extreme hydroclimate perturbations. A pattern of pronounced climatic cyclicity transformed habitats during ~275,000–60,000 years BP, a crucial phase encompassing the gradual transition from Acheulean to Middle Stone Age technologies, the emergence of *Homo sapiens* in eastern Africa, and key human social and cultural innovations. Those accumulative innovations plus the alignment of humid pulses between north-eastern Africa and the Mediterranean during the high-frequency climate oscillations between ~60,000–10,000 years BP could have facilitated the "Out of Africa" dispersal of *H. sapiens*.

IODP

Rapid metabolism fosters microbial survival in the deep, hot, subseafloor biosphere

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A fourth of the global seabed sediment volume is buried at depths where temperatures exceed 80°C, a previously proposed thermal barrier for life in the subsurface. By utilizing an extensive suite of radiotracer experiments, we demonstrate the prevalence of active methanogenic and sulfate-reducing populations in deeply buried marine sediment from the Nankai Trough subduction zone, Japan, heated to extreme temperature of up to ~120°C. Sediment cores were recovered during International Ocean Discovery Program Expedition 370. The steep geothermal gradient of ~100°C km^{-1} allowed for exploration of most of the known temperature range of life over just 1 km of drill core. Despite high temperatures, microbial cells were

detected through most of the sediment column, albeit at extremely low concentration of <500 cells per cm³ in sediment with in-situ temperatures exceeding 50°C. In millions of years old sediment, a small microbial community subsisted with high potential cell-specific rates of energy metabolism, approaching rates of active surface sediments and laboratory cultures. Even under conservative assumptions, potential biomass turnover times ranges from days to years, many orders of magnitude faster than in colder deep sediment.

Our discovery is in stark contrast to the extremely low metabolic rates otherwise observed in the deep subseafloor. As cells appear to invest most of their energy to repair thermal cell damage in the hot sediment, they are forced to a delicate balance between subsistence near the upper temperature limit of life and a rich supply of substrates and energy from thermally driven reactions of sediment organic matter.

IODP

Quantification of Himalayan erosional fluxes based on core-seismic integrated data from the Bengal Fan (IODP Exp. 354)

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Submarine fans store continental sediments and thereby act as a fundamental archive for the continental tectonic and erosion history as well as long- and short-term climate variations. The Bengal Fan is considered as the main sedimentary archive for sediment eroded in the Himalayas and thus 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).

Building on IODP Expedition 354 and seismic stratigraphy, the French-German ANR-DFG joint project 'HimalFan' (*Quantifying Himalayan Erosion Fluxes from the Bengal Fan record*) aims at further improving our understanding of the Himalayan tectonic construction and its coupling with regional and global climate. Therefore, *HimalFan* targets the reconstruction of sediment fluxes back to Miocene times and a total-flux estimation based on a multidisciplinary approach integrating seismic studies conducted in Bremen with single grain thermochronology and quartz in situ cosmogenic analyses conducted at the French partner institutes (CRPG, IsTerre).

The seismic stratigraphy along the IODP Exp 354 transect was established and spatial and temporal variability of sediment delivery was reconstructed for the Middle Pleistocene, providing unique insights into the complex 'Bengal Fan' depositional system (Bergmann et al., 2020). The investigations indicate a gradually increasing sediment flux between 650-250 ka along the IODP Exp 354 drilling transect (8°N). This may well be attributed to climatically-driven erosion rate changes, but equally likely to a change in the input function, e.g. the river network, or as an autocyclic behavior.

The seismic/chrono-stratigraphy was extended to our existing network of seismic profiles from the Bengal Fan to allow a more spatial investigation of sediment deposition. Marker horizons, such as the Middle Pleistocene Hemipelagic Layer (1.24-0.68 Ma), the Late Pleistocene Hemipelagic Layer (0.25 Ma to recent) and the C3-C4 plant transition, could be traced throughout large parts of the Bengal Fan. Additional time marker in older sediments (Pliocene/Miocene times) are constantly updated and extended by the IODP Exp. 354 scientific party and integrated into the seismic stratigraphy. Middle Pleistocene average sedimentation rates, calculated at different transects across the Bengal Fan, are in the same order of magnitude as along the IODP Exp 354 transect. Moreover, first results indicate lower sedimentation rates for the Pliocene/Early Miocene compared to the Middle Pleistocene. Further investigations of the different time intervals along the different Bengal Fan transects allows now the development of a 3D volumetric analysis of fan wide changes in sediment deposition, which will eventually be synthesized with the other approaches on Himalaya erosion rates (e.g. thermochronology, geochemistry).

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IODP

Linking phytoplankton community changes to biogeochemical responses in the cool Oligocene ocean

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Marine phytoplankton community composition plays a major role in the production and export of biomass and inorganic minerals (such as calcite) and therefore the regulation of global biogeochemical cycles and trophic energy transfer. Climate change drives changes in community structure through altered physiology, biogeography and productivity but do these assemblage responses always drive changes in community biogeochemical traits? To address this, we turn to the extensive fossil record of calcareous nannoplankton that archives the response of entire communities and their key functional traits (size, biomass and calcite) to climate change on a range of timescales. Here, we focus on the relatively understudied Oligocene 'coolhouse' era at high-latitude South Pacific Site U1553 that was drilled in 2020 during IODP Expedition 378 and recovered a relatively expanded sequence of Oligocene nannofossil ooze to chalks (Röhl et al. 2022). Long-term variability in both community composition and key biogeochemical traits (community biomass and calcite) are assessed using an innovative methodology that transforms relative abundance, coccolith size, and coccosphere geometry datasets into time-series of community size structure and its associated biomass and calcite characteristics. At Site U1553, total community biomass and calcite show a general decline from higher values in the earliest Oligocene to lower values in the middle-late Oligocene that reflects shifting abundances of the medium- and large-sized temperate-cool water species that dominate at this site throughout the Oligocene (e.g. *Cyclicargolithus*, *Reticulofenestra* and *Chiasmolithus*). Calcite:biomass is similarly responsive to community composition but always exceeds 2) 1, reflecting the 'heavily-calcified' morphologies present at Site U1553. Our results indicate that the overlapping biogeochemical traits of species present at Site U1553 during the Oligocene moderate the degree of biogeochemical impact resulting from shifts in community composition. This highlights the role of morphological diversity in biogeochemical functional traits and implies that community biogeochemical function will respond most strongly to climate impacts on community composition when replacement species have dissimilar morphological traits.

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IODP

Pleistocene evolution of eastern Pacific Southern Ocean surface water conditions

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International Ocean Discovery Program Expedition 383 recovered sediment records from three drill sites of the Eastern Pacific Southern Ocean to reconstruct the Pleistocene paleoceanographic development and sea surface processes from the open ocean environment of the Subantarctic Zone. The Pacific sector of the Southern Ocean (SO) marked by past changes in Sea Surface Temperature (SST), implies an exceptional climate sensitivity to external and internal forces at both millennial and orbital timescale. Glacial-interglacial SST changes in the Subantarctic Pacific sector of the SO imply large latitudinal shifts in Antarctica´s Polar Fronts, i.e., the Subantarctic Polar Front (SAF). These shifts control the extent of sea ice, which appears to play a key role in the physical, chemical and biological properties of SO surface water. Only little information is available from the long-term SO climate development during the Pleistocene which matches the time span of the new "Oldest Ice" ice core intended to reaching back up to 1.5 million years. The sediment records of Expedition 383 will allow for an improvement of our knowledge and an establishment of time series of SST variations, winter sea ice (WSI) extent and productivity changes of the Pleistocene eastern Pacific SO (Sites U1539, U1540 and U1541).

Main goal of this project is to establish high resolution diatom records from the three Subantarctic central eastern Pacific sites to reveal Pleistocene environmental changes focusing on peak interglacials (e.g., MIS 5, MIS 9 and MIS 11) and especially the super interglacial MIS 31 (1.07 Myr). To address past changes in SST, sea ice extent and productivity, palaeobiological analyses (diatom census) will be applied to Sites U1539, U1540 and U1541 and compared with geochemical proxy results. Transfer-functions applied to the diatom census will provide information on changes in SST and WSI concentration from the Early Pleistocene 41,000-year glacial periodicity across the Mid-Pleistocene Transition to the Late Pleistocene 100,000-year periodicity, with the results intended to be correlated with the "Oldest Ice" record and to be compared with the POLARSTERN PS58/273-1 Antarctic Zone sediment core. A further opportunity of the diatom analysis will be the refinement of the Subantarctic Pacific diatom stratigraphy.

IODP

Pleistocene variations in Antarctic Intermediate Water

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The Antarctic Intermediate Water (AAIW) forms an integral part of the global thermohaline circulation as it redistributes heat, salt, CO_2 and nutrients from the Southern Ocean to the nutrient deprived tropics. Although there is clear evidence that the transport and composition of the AAIW played an important role in the climate change of the last deglaciation, there are only a few longer records of the AAIW variability. Our goal is to produce records of the variations in AAIW water mass sourcing, nutrient content and temperature in the south Pacific and Atlantic basins spanning the last 1.2 million years. Our study is based on two intermediate water depth drill cores from the open ocean, far from continental sediment input to avoid potential sedimentary overprinting. In the South Atlantic, DSDP Site 516 on the Rio Grande rise at 1300m water depth is located in the modern-day core of AAIW and in the South Pacific, IODP Site U1510 at 1238m water depth in the central Tasman Sea is currently bathed by a mixture of Southern Ocean AAIW and Tasman AAIW. At both locations high resolution core scanning data have been used to generate a spliced record and the age model is established based on benthic foraminiferal oxygen isotopes. To constrain the AAIW composition trace metal proxies for temperature (Mg/Ca) and nutrient content (Cd/Ca) as well as the stable carbon isotope composition of benthic foraminifera have been measured. To reconstruct the routing of AAIW during the Pleistocene we employ the neodymium (Nd) isotope composition of the authigenic coatings of mixed planktonic foraminifers supplemented with rare earth element data and the Nd isotope signatures for selected detrital silicate samples. These data allow the assessment of whether the authigenic Nd isotopes truly reflect a water mass signal or the extent of sedimentary overprinting. Finally, these data will illuminate the role of AAIW variability in glacial/interglacial climate change for key glacial-interglacial periods before, during and after the mid Pleistocene transition.

ICDP

Tectonic Deformation and Lake Depositional Processes within Lake Issyk Kul – Kyrgyzstan- Insights from new High-Resolution Seismic and Acoustic Data

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Based on a research cruise in 2019 with R/V Moltur, two projects have been carried out to shed light on the sedimentary setting and tectonic framework at Lake Issyk Kul to prepare a future ICDP drilling proposal for lake sediments.

The Issyk Kul basin is located in the Tien Shan mountain range in Central Asia. While the basin remained stable in the geological past, previous studies have recognized active tectonic structures within the eponymous lake, which largely occupies the basin. These structures are anticlines and could archive a basinward deformation shift from the bordering fault systems into the basin interior.

To verify this shift, the high-resolution seismic data set acquired on Lake Issyk Kul has been processed, interpreted and geometrical approaches have been applied to extract tectonic parameters from the seismic profiles. The investigation reveals the anticlines as actively growing right-stepping en-echelon folds, which show an age of about 1.9 Ma and originate from a deep (2.8 km) detachment. But the southeastern part of the lake and basin does not follow the differential subsidence found for the rest of the working area to the same extent.

In order to explain both observations, a blind footwall shortcut beneath the anticlines is proposed, which originates from the bordering fault system in the south and shows a dextral strike-slip as well as a reverse component. The right-lateral movement is clearly archived by the right-stepping anticlines, whereas the reverse component is deduced from the interruption of the differential subsidence. Hence, the basinward shift of deformation is confirmed. However, the ongoing differential subsidence in the rest of the basin restricts that shift to be partial and evidence the simultaneous activity of the bordering fault systems and the anticlines. Thus, the structural framework of the Issyk Kul basin needs to be considered on the search for suitable drill sites, which provide several million years of continuous records.

The tectonic activity in the region also include mega-earthquakes, and thus the depositional setting of the lake may have been affected. Sub-bottom profiler data (6 kHz) in the deep basin of Lake Issyk-Kul have been investigated, showing a conspicuous acoustically transparent layer, but completely absent on slopes and in the deltas of the lake. It covers an area of 1003.9 km2 and represents a volume of roughly 1 km3. The layer has been interpreted as a "homogenite" type deposit due to its distribution and spreading throughout the deep basin that seems to point towards a gravitational settling as depositional process. The volume of the layer although considerably big compared to other intra-mountainous lakes, seems to fit to the volume of other homogenite layers deposited in other constrained basins with a comparable size and water depth. Two deposition models are suggested, and consequences of these features for the sedimentary record as a whole are discussed.

IODP

The role of South Pacific dust provenance changes in Pliocene-Pleistocene climate variability (IODP Expedition 383)

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Mineral dust is an important component of the Earth's climate system. It has been hypothesized that the increase in airborne iron (Fe) supply to the Fe-deficient Southern Ocean promoted primary productivity resulting in a net drawdown of atmospheric CO_2 [1]. This important feedback mechanism was suggested to have forced the climate system towards full glacial states during the Late Pleistocene [2, 3]. Similarly, the Southern Ocean dust-Fe feedback has been considered to explain the cooling trends of mid-Pleistocene glacial intervals and during the late Pliocene onset of the Northern Hemisphere Glaciation [2]. Recent work from the South Pacific showed that the Southern Ocean dust-Fe feedback is critically linked with dust emissions from specific Southern Hemisphere source regions and their transport by the westerly wind system [4]. Preliminary results from site PS75/056-1 (survey core for IODP Expedition 383 site U1540) show that the circumpolar transport of dust from Central South American sources plays a dominant role for the dust deposition in the South Pacific Subantarctic Zone (SAZ) over the last 260 ka. The combined Australian and New Zealand dust input is overall secondary, but their contributions increase during the later stages of the last two glacial cycles (Fig. 1a, c). The dust provenance variations correspond systematically with dust grain size data [5] and dust-Fe fluxes [6] highlighting the value of complementary quantitative proxy information for reconstructions of past dust cycle changes in the Southern Hemisphere (Fig. 1a, b).

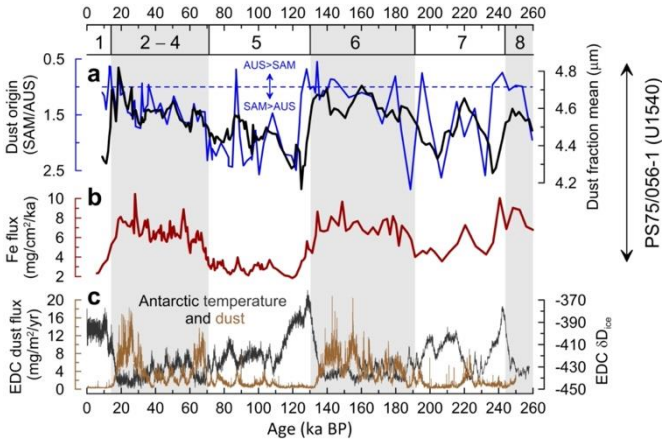

Figure 1: Indicators of glacial-interglacial dust cycle variability in the South Pacific SAZ. a Ratio of South American (SAM) and Australian/New Zealand (AUS) dust contributions compared with the mean particle size of the dust fraction in core PS75/056-1 [5]. b Fe flux data for core PS75/056-1 reconstructed using 230Th as constant flux proxy [6]. c Antarctic EDC ice core deuterium [8] and dust flux [9] data.

The new project is designed to build upon these recent findings and investigate the role of changes in South Pacific dust provenance in the climate variability of the last ~5 Ma using marine sediments from IODP Expedition 383 sites U1540 and U1541 [7]. The dust fractions will be extracted from the samples and analyzed for their geochemical fingerprint (rare earth elements, and lead, neodymium, and strontium isotopes). Source apportionment with Bayesian mixing models will quantify the contributions from the different potential source areas in every individual sample. These data will be used to identify transport routes and mechanisms of dust delivered to the study area during the last ~5 Ma. The same sediment cores are used by national and international project partners to reconstruct (lithogenic and biogenic) particle fluxes and to analyze dust particle sizes. The combination of these datasets will provide, for the first time, a comprehensive picture Southern Hemisphere dust cycle changes and their role in Pliocene-Pleistocene climate variations.

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ICDP

ICDP project "Drilling Overdeepened Alpine Valleys" (DOVE) - status report of boreholes drilled in 2021

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The ICDP project DOVE attempts to quantify and qualify the timing and extent of Pleistocene glacial events around the Alps by drilling the overdeepened valleys. To this end, we drilled two sites in the Rhine Glacier system in 2022) the distal site of Tannwald, Germany and the more proximal site of Basadingen in Switzerland.

At Basadingen, pre-drilling seismic showed a highly dynamic glacial site, with inclined unconformities that indicate multiple glaciation events. The borehole was cored to a depth of 253 m from May 25th – October 13th 2021, reaching just above the predicted base of the overdeepened valley and the Tertiary Molasse substrate. From core-catcher material, five different facies were encountered: 1) a thin silty-to-sandy unit at the top, underlain by 2) diamictic gravel, and by 3) a partly sandy-silty gravel. Facies 4) consists of fine to medium sand with partially diamictic texture, whereas facies 5) comprises gravel layers of up to 15-20 m thickness with high permeability. Facies 4 and 5 intercalate several times. The core has now been opened and passed thorough MSCL, so that we have gamma density and magnetic susceptibility data to substantiate our other information.

The Tannwald site is located near the town of Winterstettenstadt, close to the front of the Rhine Glacier. Three boreholes were completed; two flush boreholes and one core borehole were drilled to depths of 165 m, 155 m and 163 m, respectively from 6th April to 3rd December 2021. Coring was achieved by ramming to 82 m, and then changed to rotary drilling to the end depth. Because casing was not used below 45 m in the flush boreholes (in the core borehole below 82 m), we were able to acquire open-hole borehole geophysics. We recognise mostly coarse-grained gravels and sands with diamictons in the upper 47 m, which is followed by finer-grained basinal clastics with dropstones (Fig. 1) to 137 m, which then becomes coarser grained with diamictons at the base of the overdeepened valley at 139-154 m.

We drilled a further 10 m in to the Tertiary Molasse, which consists of carbonate-cemented sand- and siltstones. The total core recovery was 95%.

This core is now in the process of being opened and passed through the MSCL. The three boreholes are still open and form the basis for the crosshole seismic project of Sarah Beraus (see poster).

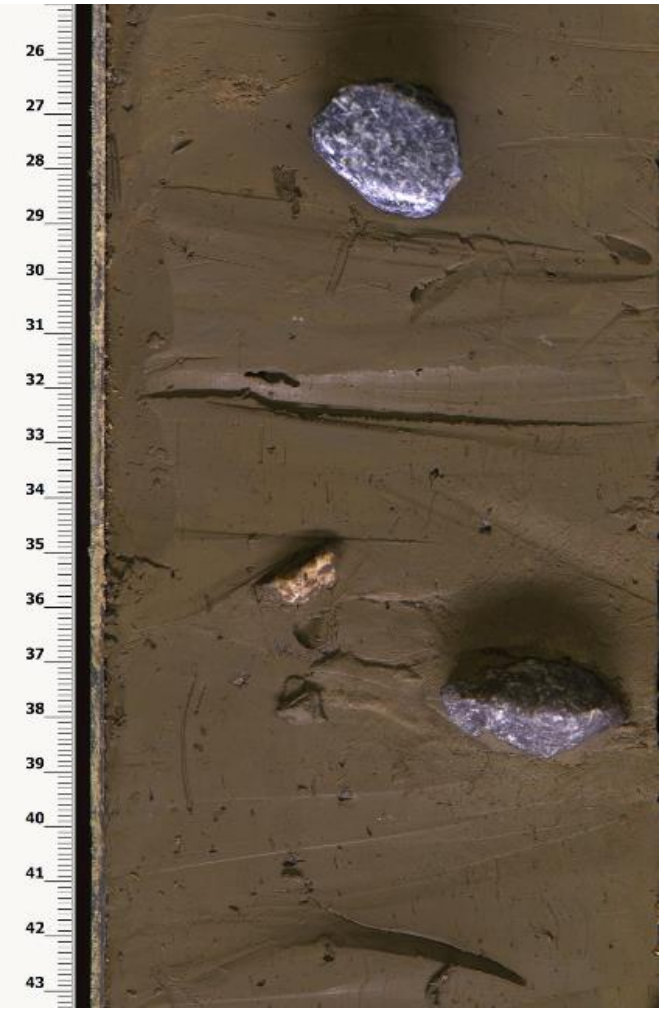

Figure 1 : Dropstones in the Tannwald borehole at a depth of 87 m.

In both cores, we plan to carry out an extensive dating approach, using 1) OSL, 2) Pore-water dating using noble gases, and 3) cosmogenic nuclide dating. In addition, samples were taken under sterile conditions to probe these sediments for deep life. Geochemical groundwater sampling in Tannwald has shown the basal water is unlike Quaternary groundwater, which suggested that pore-water dating might be possible.

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ICDP

Multi-scale calibrations of rock masses electrical properties around the DIVE drillsite

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This project contributes to, and advances, the likely outcomes of the ICDP-supported project DIVE (Drilling the Ivrea-Verbano ZonE). In it, we will calibrate mid- to lower-crustal metamorphic rocks' compositions, micro- to macrostructures, and fluid contents to their electrical properties as measured by laboratory, field, and borehole methods across mm- to km-scales. The results will change geologists' and geophysicists' ability to interpret the distribution of mineralized rock types and circulating (e.g. geothermal) fluids within the globally-unique sequence and structures surrounding the DIVE DT-1a and DT-1b drillsites from electrical survey data. They will also be able to be applied more broadly to better understand the distribution of these sort of geological resources at depth in other orogenic belts worldwide.

Our methodology comprises;

(i) Measurement of the electrical properties of representative rocks from the Ivrea-Verbano Zone both in the laboratory at a range of pressures and temperatures similar to those likely encountered at depth in the boreholes, and in new coupled borehole-surface electrical surveys

(ii) Characterisation of the structures and compositions of those same rocks at microscale using electron microscopy and synchrotron computer tomography, at mesoscale through CT scanning of drillcores and automated image analysis of those results, and at kilometer scale by field analysis,

(iii) Calibration of computed electrical responses of the observed micro- to macrostructures to our various real measurements allowing prediction of electrical responses of structurally-different materials, and

(iv) Calculation of bulk properties of representative volumes of the various heterogeneous materials to dramatically refine the ability to invert for fine structural and lithological variations from coarser resolution surveys.

Our work will be complementary to other comparisons of petrological and geophysical datasets (e.g., seismic velocity, density, thermal parameters) planned during DIVE. The overally collaboration will provide a novel calibration of petrophysical data to rock mass properties in lower crust and upper mantle lithologies.

IODP

Cyclostratigraphic investigations with special emphasis on half-precession signals using XRF-data from ODP Site 663 (Eastern Equatorial Atlantic)

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The characteristics of half-precession (HP) cycles (~9,000 - 12,000 years) are still poorly understood, despite their appearance in numerous records. Previous studies on European terrestrial and marine records indicate a

connection of the HP-signal to low latitudes. We investigate HP-cycles in equatorial regions to study the assumed origin of this signal.

Spectral analysis, evolutive approaches and correlation techniques will be used on records from ODP Site 663 and 662 to identify the HP-signal in elemental ratios reflecting e.g. terrigenuous input and/or bioproductivity. Filters have been designed to remove the classical orbital cycles (eccentricity, obliquity, precession) to isolate the HP-signal and to determine its temporal evolution.

We present first results of a larger project which has the overall objective to characterize the HP-signal across the Mid-Pleistocene Transition (MPT) at Site 663 and 662. Over the course of the MPT, the ~100 kyr-eccentricity cycles supersede the 41-kyr obliquity as the primary driver of climate forcing. As precession is modulated by eccentricity, a similar relationship is assumed for HP and eccentricity. Our preliminary analyses show an enhanced HP-signal in the younger, 100-kyr eccentricity world, but also in the late MPT which is partly influenced by the 41-kyr obliquity world. Cyclostratigraphic investigations of high-resolution XRF data will provide a clearer insight into the ambiguous role of HP during the MPT and the late Pleistocene.

Further objectives of the investigations will be to link the orbital patterns of Site 663 to terrestrial records, e.g. from the ICDP project on Lake Bosumtwi (Ghana). This will contribute to a better understanding of paleoenvironmental processes in Equatorial Africa.

ICDP

Past temperatures of the Dead Sea during the last Deglaciation- Insights from Clumped Isotope Thermometry

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The Mediterranean Sea is referred to as a “climatic hot spot” and warms twice as fast as the global ocean, which bears serious consequences for regional hydroclimates (MedECC, 2020). Past intervals of global warming can help us to pinpoint the processes driving temperature and hydroclimatic changes in order to better manage water resources. The Dead Sea is a terminal lake located in the Eastern Mediterranean, which is an area prone to droughts and extreme rainfall events. In addition, changes in lake levels are directly linked to the precipitation-evaporation balance in its drainage region (Müller et al., 2022). Climate-induced lake level fluctuations in the Dead Sea have been extensively investigated, but changes in lake-water temperature have so far not been reconstructed.

For our study, we use ICDP core 5017-A, which has been extracted from the deepest part of the Dead Sea and covers the last two glacial-interglacial cycles. The investigated time interval of the deglacial warming between 17ka to 11.7ka includes the rapid climatic changes of the H1-event, The Bolling-Allerod warm period and the Younger Dryas. In order to reconstruct past lake-water temperatures, we used the clumped isotope thermometry on authigenic aragonite. Individual aragonite layers were sampled on resin-embedded sediment blocks in varved intervals of the core and will be compared to obtain statistically sound measurements. This innovative technique will be combined with other type of data available or to be acquired for the core, such as XRF scanning, microfacies analysis, stable oxygen isotopes and radiogenic strontium isotopes to provide a hydroclimatic context. Here we present first results and discuss potential interpretations and new insights on temperature changes in the Dead Sea and their impact on hydroclimates during the last deglaciation.

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IODP

A 5,3-Myr Record of Dust Deposition in the South Pacific Ocean from IODP expedition 383

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The Southern Ocean is a key player in regulating atmospheric CO2 variations through the biological utilisation of nutrients supplied by atmospheric dust. Sediment records and model simulations show that higher mineral dust fluxes during glacial periods coincide with increased bioproductivity and lower atmospheric CO2, which has been associated with iron fertilisation. However, direct measurements of dust deposition over the Southern Hemisphere oceans are scarce and there is a great need for an expanded geographical coverage of direct observations of dust deposition. This is particularly true for long-term Plio-Pleistocene dust records from the Southern Ocean, which are presently confined to the subantarctic South Atlantic where dust almost entirely originates from Patagonian sources. Here we present the first long records form the South Pacific dominated by Australian dust sources. Our records are based on a 145 m long sediment sequence (Site U1541) recovered during IODP expedition 383 in the central South Pacific spanning the last 8 Myr. We present grain-size data, terrestrial biomarkers and dust- and sediment fluxes and relate this to global and regional paleoclimatic trends. By using end-member modelling we aim to disentangle the dust signal from current-sorted sediments. Our final goal is to improve our understanding of dust-iron coupling from the largest Southern Ocean sector and its impact on atmospheric CO2 and global climate.

ICDP

High-resolution downhole gamma ray data from Lake Bosumtwi (Ghana) – Towards an astronomical age model and implications for environmental reconstructions

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Lake Bosumtwi evolved in a 1.07 million years old meteorite crater in Ghana – an area that is especially climate sensitive due to its position in the tension field between the North African Monsoon and the Harmattan bringing dry and dusty winds from the Sahara. Yet, detailed climatic and environmental reconstructions are largely constrained to the Late Pleistocene, despite the potential of the limnic archive to inform us about the living environment in the cradle of our species. The major reason for this is the lack of a robust age model that covers the whole last million years. We obtained both logging and core scanning gamma ray data of the ~300 m lacustrine sedimentary sequence drilled in Lake Bosumtwi by the International Continental Scientific Drilling Program in 2004. Based on this, we aim to create an astronomical age model that can be directly compared to dated section of the Upper Pleistocene, but extends also further back in time. Gamma ray data potentially indirectly inform us about past moisture contents of lake sediments and hence, about the hydrological situation as e.g., successfully applied for Lake Chalco in the tropics (Mexico). Both, the age model and the paleoenvironmental information are promising to improve our knowledge about the environmental conditions beyond the last glacial cycle in the cradle of humankind that is so

far poorly understood.

ICDP

Three-component borehole magnetics in the COSC-2 drill hole

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The COSC-2 project aims to understand the main Caledonian décollement as well as related faults, providing an insight into deformation processes. Preliminary results of the COSC-2 borehole indicate a network of mafic intrusions similar to 1.2 Ga dolerites from the Fennoscandian Shield (Lescoutre et al. 2022). These intrusions form an approximately 240 m thick dolerite section between 1590 m and 1830 m that corresponds to a distinctive seismic reflector and causes a prominent magnetic anomaly.

The measurement of wireline magnetic data in the COSC-2 drillhole was performed with a Dipmeter by the ICDP Operational Support Group (OSG). This tool measures the electrical conductivity along the drillhole wall. In order to reorient the conductivity readings, the tool utilizes a three-component magnetometer and a two axes inclinometer. However, the magnetometer of the dipmeter is not intended for scientific analysis but used as orientation aid and we had to assume that the calibration did not meet scientific requirements. Therefore, we developed an in-situ calibration method based on a multi-position calibration which allows the calibration of a borehole magnetometer using two or more logging runs. This newly developed calibration scheme is not limited to this specific setting but can be applied with a multitude of borehole tools to improve accuracy of orientation modules or, like in this project, to obtain high quality magnetic data from a sonde not specified for borehole magnetometry.

For further processing, the calibrated data had to be reoriented into the Earth's frame of reference. Here, we used Inclinometer data from the dipmeter in combination with the course of the drill hole which was determined by Henning Lorenz (Uppsala University), using a gyro tool. We were able to reorient the recorded magnetic field with an accuracy of 0.1° in inclination and 1° in declination (Fig. 1).

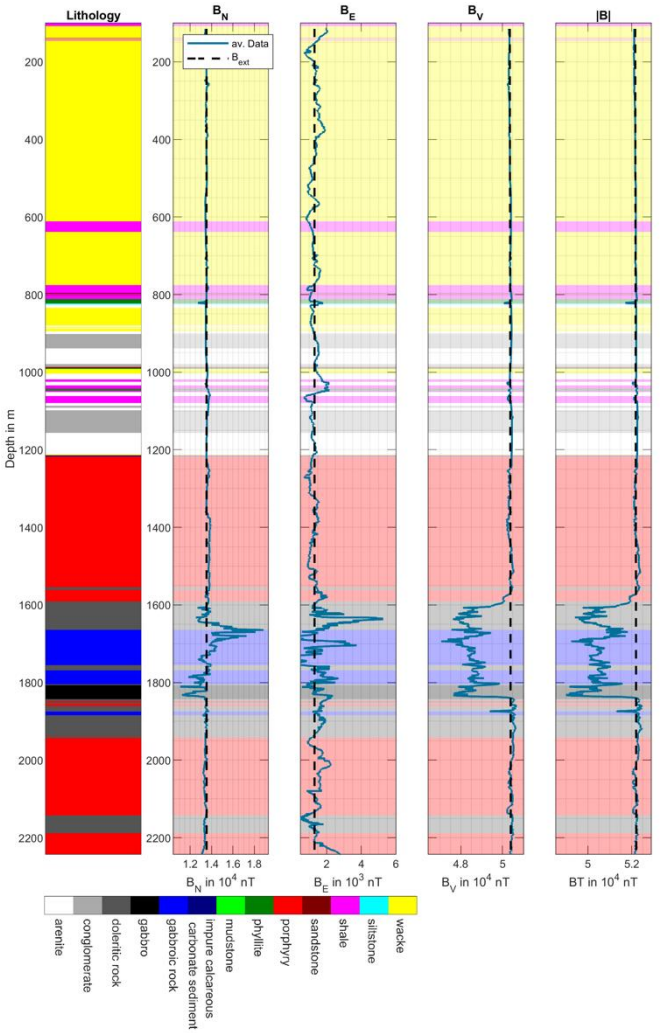

Figure 1: Preliminary lithology obtained at the core description and reoriented magnetic data against the IGRF. While most of the borehole shows only a minor magnetic anomaly, a sequence of dolerite and gabbro between 1600 and 1850 m depth show a fairly large magnetic anomaly signal.

Using the calibrated and reoriented magnetic data, we calculated a model of the remanent magnetisation using the model by Bosum and Scott (1988). This model assumes horizontal layers and is based on an infinitely extended horizontal cylinder with a vertical borehole in the centre. In order to validate the wireline magnetisation model, we drilled 34 plugs in various depths and measured the natural remanent magnetisation (NRM) and susceptibility at the core laboratory in Grubenhagen, operated by LIAG. Analysing the NRM measured on the plugs, we observed significant deviations from the wireline magnetisation model, indicating the need for high-resolution measurements on the cores. We developed a setup that enables us to perform magnetic gradient measurements on 1 m long sections of the core with a spatial resolution of 1mm.

During the Sampling Party in June 2022, we measured a total length of approximately 190 m of core. We separate the measured core sections into 10 cm long segments and calculated the remanent magnetisation and susceptibility for each segment.

The susceptibility derived from the core sections is in good agreement with the wireline measurements. The NRM calculated from core and plug measurements also match very well. Comparing the NRM calculated from the cores to the wireline model, we see deviations that are significant in some depths (e. g., at 1638 m in Fig. 2). The deviations indicate that the assumed model of layered rock units is not sufficient to characterise the complex structure of the Caledonian décollement. In order to improve our model, we plan to incorporate vertical seismic profiling data to develop a 3D model of the magnetised structure in the vicinity of the drill hole.

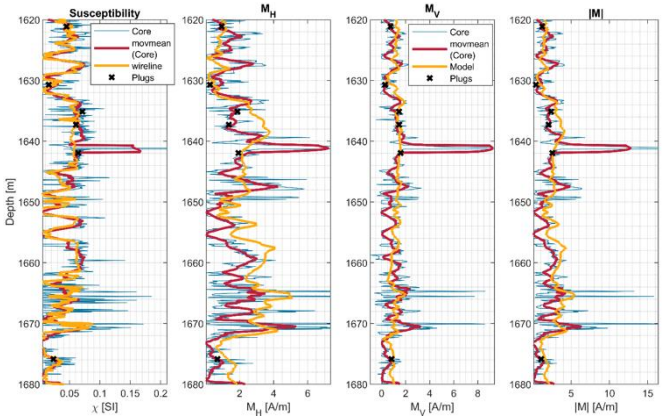

Figure 2: Comparison of susceptibility and remanent magnetisation for the different measurement methods (excerpt). The blue line shows the values calculated from the measurements on the core. In order to account for the higher resolution of the core data, they are averaged over 1 m for better comparability (red line). The yellow line denotes the wireline susceptibility measurement (left panel) and modelled magnetisation, respectively. The black crosses indicate the results of the measurements on the plugs. The horizontal and vertical components of the remanent magnetisation (middle panels) are given with respect to the Earth's frame of reference.

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ICDP

Isotope signatures of diagenetic siderites from Lake Towuti's 1Ma ferruginous archive

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Lake Towuti is a deep tectonic basin surrounded by ultramafic rocks and lateritic soils. Erosion of the catchment supplies Lake Towuti with little sulfate but considerable amounts of iron (oxyhydr)oxides (Vuillemin et al., 2016). Under stratified conditions, particulate iron partially dissolves in the monimolimnion following microbial reduction of ferric iron (Bauer et al., 2020). The extreme scarcity of sulfate and nitrate/nitrite in Lake Towuti's anoxic bottom waters represents ferruginous conditions that are analogous to those of the early Earth's oceans (Friese et al., 2021). Furthermore, its geographic position in central Indonesia and relatively great age makes the lake a prime recorder of paleoclimatic changes and depositional redox processes associated with the Western Pacific circulation over the last 1Ma (Russell et al., 2016). In May to July 2015, the Towuti Drilling Project of the International Continental scientific Drilling Program (ICDP) recovered a 100 m long core (TDP-1A), drilled with a contamination tracer mixed into the drilling fluid to identify core sections suitable for geomicrobiological studies (Friese et al., 2017).

Siderites ($FeCO_3$) were recovered from split core halves in 50 distinct layers, whereas vivianites ($Fe_2[PO_4]_2 \square 8H_2O$) were found in 5 different horizons. SEM and TEM imaging documented the growth of siderites from micritic phases into mosaic monocrystals, developing into twins and aggregates with increasing depth of burial (Vuillemin et al., 2019). High-resolution imaging of vivianites also revealed continuous growth of crystals from tabular to rosette habits that eventually form large vivianite nodules (up to 7 cm) in the sediment. Mineral inclusions like framboidal magnetite (Fe_3O_4) and millerite (NiS) reflect microbial reduction of iron and sulfate antecedent to the formation of siderite and vivianite (Vuillemin et al., 2020). These mineral analyses integrated with detailed pore water geochemistry show that the precipitation of magnetite, millerite, siderite, and vivianite in soft ferruginous sediments stems from gradual saturation of pore waters during microbial reduction of electron acceptors and concomitant organic matter remineralization. Nevertheless, the presence/absence of siderite and vivianite in specific sedimentary layers may relate to past dynamics in the lake's water column and at the sediment-water interface, since ensuing variability in the relative burial of ferric iron and organic matter are decisive on subsequent diagenetic processes in the sediment.

To disentangle climatic and diagenetic signals, we analyzed oxygen, iron, and carbon isotopes using siderite as an environmental proxy. We show that siderite oxygen isotope compositions ($\square^{18}O$) reflect in-lake hydrological conditions, as for instance lake evaporation during the Last Glacial Maximum. Low iron isotope values ($\square^{56}Fe$) record oxygenation events of bottom waters over geologic timescale, with minor diagenetic partitioning of Fe isotopes by microbial iron reduction after deposition. In contrast, negative $\square^{56}Fe$ values measured for vivianites indicate incorporation of kinetically fractionated light Fe^{2+} into the crystals, pointing to diagenetic dissolution of ferric/ferrous phases. The carbon isotope compositions ($\square^{13}C$) of siderites reflect incorporation of biogenic HCO_3^- from pore waters during sediment organic matter remineralization lasting over ~200 ka years after burial. Positive $\delta^{13}C$ excursions indicate increased biogenic production of methane. However under decreased sedimentation rates, diffusion across the sediment-water interface takes place and aligns the isotope signatures of bottom waters to those of pore waters during initial formation of siderites (Vuillemin et al., 2022). As microbial reduction of ferric iron and oxidation of organic matter proceed and saturate pore water with respect to siderite, overgrowth on nuclei continues during ~1Ma of burial, which partially mutes the environmental signal inherited from paleolake bottom waters.

To conclude, while the identification of successive mineral phases, namely magnetite, millerite, siderite and vivianite, provides a means to trace microbial processes of early diagenesis in soft ferruginous sediments, the environmental record contained in siderite grains successively integrates both depositional and early diagenetic signals over relatively short geologic timescales. The morphologies, inclusions and isotope compositions of such minerals can thereby be used and extrapolated to better constrain ancient and modern sediment records.

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ICDP

Constraining the magmatic plumbing system of the Snake River Plain volcanic province, USA: contributions from crystal mush fragments

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The Snake River Plain (SRP) volcanic province, located in the western United States, is a prime example of a continental hotspot. It records 12 million years of bimodal volcanism, with early rhyolite caldera complexes covered by extensive younger basaltic flows. The ICDP Snake River Scientific Drilling Project (HOTSPOT) completed three drill holes in the SRP, which combined offer an overview of the entire volcanic sequence.

The Kimana drill core samples 1912 m of continuous basalts, which were erupted over a time span of 6 million years. The basalts generally consist of mm- to cm-scale macrocrysts of plagioclase and olivine, interpreted to be entrained mush fragments, in a glassy to fine-grained groundmass of plagioclase, olivine, pyroxene and oxides. Anorthite contents vary up to 25 % within single plagioclase macrocrysts, and both glomerocrysts and individual macrocrysts exhibit complex zoning patterns, with single plagioclase crystals regularly recording different types of zoning (normal, reversed, oscillatory, patchy), resorbed cores and repeated internal resorption surfaces. This indicates a complex magmatic system, in which plagioclase crystals which formed in different environments were entrained by ascending magma and erupted together.

We present an overview of textural and compositional data from the plagioclases within the Kimana core and a classification of the complex zoning types. By grouping plagioclases with a similar history and measuring compositional changes within the crystals, we can constrain the pre-eruptive storage conditions of the magma by proposing a sequence of events (changes in P and T, recharge events, magma mixing). This allows us to reconstruct how the magma was stored and entrained, how separate reservoirs were connected and how P and T in the system changed, thereby enabling us to build a model for the magmatic plumbing system of the SRP basalts.

ICDP

Project SEIZE - SEismic imaging of the Ivrea ZonE

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The Ivrea-Verbano Zone (IVZ) in the Italian Alps exhibits an almost complete archetype of continental crust–upper mantle transition at and close to the Earth surface. After Mesozoic thinning the IVZ was tilted during Alpine convergence and most of the pre-Alpine geometry is well preserved. As the structurally deepest section is of interest for scientific drilling (see DIVE, www.dive2ivrea.org), we aimed at characterizing extent and shape of this area and especially the peridotite body near Balmuccia with project SEIZE (SEismic imaging of the Ivrea ZonE).

For this purpose, a controlled-source seismic experiment was carried out along two crossing profiles with a total length of ~27 km running along (NNE-SSW) and across (W-E) of the Balmuccia peridotite. In total, 432 vibro points were acquired with a nominal distance of ~60 m which were recorded using a fix-spread (110 receivers, ~250 m spacing) and a roll-along setup (330 receivers, ~20 m spacing). However, the difficult terrain setting (deep mountain valleys) results in complex wave propagation that is challenging for conventional reflection seismic processing methods.

We complemented the data analysis by performing an inversion based on Markov chain Monte Carlo techniques to derive an isotropic 3D P-wave velocity model based on ~24,000 first break travel times (refracted phases). The resulting seismic P-wave velocities (Vp) range from 4.5 km/s to 7.5 km/s. The most prominent feature of the 3D tomography model is a pointy high-velocity body (Vp increases from 6 to 7.5 km/s) that broadens downwards and peaks the surface East of Balmuccia at a location coincident with the exposed Balmuccia peridotite. To the West, it is limited by the Insubric Zone (ISZ), the Europe–Adria plate boundary, which is marked by a sharp velocity change from low Vp in the West to high Vp in the East.

Considering rock physics, high resolution gravity and other geophysical data, we interpret this high-velocity body as mantel material (peridotite) which requires a revision of former models. We favor a model that the contact between the Balmuccia peridotite and the Permian mafic magmas might represent a fossil continental crust-mantle transition zone.

IODP

Subantarctic surface ocean temperatures in the Eastern South Pacific since the Late Miocene (IODP Expedition 383)

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The Antarctic Circumpolar Current (ACC) is the world's strongest zonal current system linking all three oceans. The ACC therefore integrates and responds to global climate variability. Going back in time, however, information on the Cenozoic palaeoceanography derived from deep-sea drilling records is lacking for the Pacific sector of the ACC. To improve our understanding of Late Miocene to Holocene atmosphere-ocean-cryosphere dynamics in the Eastern South Pacific, we reconstructed surface ocean temperatures from drill Site U1543 located at ~3850 m water depth where a

complete composite sediment record has been recovered during IODP expedition 383 in the northern ACC system close to the South American continent and the Drake Passage (Lamy et al., 2019). The initial ship-board age model suggests that the 376.3 m long composite sequence covers the last ~8 Ma, and can be lithologically divided in an upper Pleistocene to Holocene unit and a lower late Miocene to early Pleistocene unit (Lamy et al., 2019). Our preliminary alkenone-based sea surface temperature (SST) record documents a pronounced SST cooling during the Late Miocene Cooling (LMC) of about 9°C. In combination with published SST records from the Pacific (Herbert et al., 2016; Liu et al., 2019), we show that the equator-to-pole temperature gradients increased from 13°C to 19°C during the LMC, which was stronger than in the SW Pacific increasing from 4°C to 8°C. A stronger cooling and larger temperature amplitudes at U1543 may imply a stronger sensitivity of the SE Pacific to the frontal dynamics and changes in the West Antarctic Ice Sheet. A SST minimum around 6 Ma most likely caused or at least mirrors the onset of major Patagonian Glaciations, which is associated with aridification and less dense vegetation cover as suggested by long-chain *n*-alkanes. SSTs in the SE Pacific show further a long-term cooling during the early Pliocene, whereas during the mid-to-late Pliocene temperature amplitudes increased accompanied by an intermittent vegetation re-growth in Patagonia. In contrast to the North Atlantic and North Pacific, our reconstructed equator-to-pole SST gradients indicate a slight warming in the SE Pacific during the intensification of the Northern Hemisphere Glaciation and cooling not before 2.5 Ma. We hypothesize that this difference might be related to reorganisations in the global meridional ocean circulation and a dynamic West Antarctic Ice Sheet during the Pliocene-Pleistocene transition affecting N-S-shifts of the frontal systems and water transport across the ACC and through the Drake Passage (Gohl et al., 2021).

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IODP

Cycles, cycles, cycles – a new Maastrichtian to Late Campanian composite record from equatorial Pacific Shatsky Rise ODP Leg 198

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The latest Campanian to Maastrichtian (75-66 Ma) time is particular interest, because Earth's overall warm climate cooled in these periods to an extend that possibly allowed ephemeral glaciations of the poles. Not only because of these facts this time interval has increasingly moved into the focus of paleoclimatic research urgently requiring for extended high-resolution, orbitally-calibrated records. Carefully investigating of current benthic stable isotope data compilations for this interval for the Pacific and Atlantic Ocean unveils severe issues. These compilations cannot resolve Milankovitch frequencies and therefore lack astronomically tuned age models. Large uncertainties and errors in the applied age models led to interpolation of data over thousands of years losing important detailed information or even missing transient events. Merged data from various single holes and a variety of latitudes and longitude, with exhibiting high level of drilling disturbance in some cases, add additional levels of uncertainties. In summary, the current available data do not provide the information required for studying high-resolution climate variability in toward understanding detailed processes of the latest Cretaceous Greenhouse world.

Here we present new geochemical data covering the latest Campanian to Maastrichtian equatorial Pacific Sites 1209 and 1210 (ODP Leg 198, Shatsky Rise). We obtained X-ray fluorescence (XRF) core scanning elemental intensities that allow to extend the composite records beyond the K/Pg boundary by more than 60 meters, equivalent to more than 7 million years. Barium shows persistent cyclicity related to eccentricity modulated precession. Previous studies on Sites 1209 and 1210 material have severely aliased the high-frequency precession signal due to low sample resolution. Based on our observation we designed a sampling plan to avoid aliasing of the primary precession cycle signal and analyzed 1578 bulk stable isotope samples (1260 from Site 1209; 318 from Site 1210) resulting in an almost 67-m long bulk carbon isotope record at 5 cm resolution. Bulk carbon isotope data show a strong imprint of eccentricity that can be utilized to tune the record to the stable 405-kyr eccentricity cycle independent from the precession dominated Barium record. We sampled the composite 1209/1210 record at high-resolution to perform benthic foraminifer stable carbon and oxygen isotope analysis on tests of *Nuttallides truempyi* and *Oridorsalis umbonatus*. Almost 1500 samples have been wet sieved, documenting extensive variations in the coarse fraction related to precession cyclicity. Covariance between Barium XRF and coarse fraction data suggests a causal linkage via productivity in the surface ocean. We will present first results from benthic foraminifer stable isotope analysis and compare to previous lower resolution records.

IODP

The response of terminal Maastrichtian deep-sea echinoids to the Latest Maastrichtian Warming Event (LMWE) and the K/Pg Boundary Event

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Because onshore deep-sea sediment archives are rare, the fossil record of benthic deep-sea macrofauna is scarce. However, considering not only the entire test but also disarticulated fossil remains, deep-sea drill cores represent a yet unexplored but powerful source, in particular for echinoderm ossicles (Thuy et al. 2012). Here, we tested the potential of echinoid spines for reconstructing echinoid dynamics prior to the K/Pg boundary, based on *c.* 1,000 echinoid fragments from terminal Maastrichtian to lower Paleocene sediment samples off Newfoundland (Site U1407C, palaeowater depth *c.* 1,700 m; Site U1403B, palaeowater depth *c.* 3,600 m; IODP Expedition 342). The echinoid assemblages are dominated by spines of Atelostomata (Holasteroida, Spatangoida). Cidaroid (regular echinoids) spines are rare, but, surprisingly, spines of the Echinothurioida spines (regular echinoids: "leather urchins") fairly frequent but limited to Site U1403B.

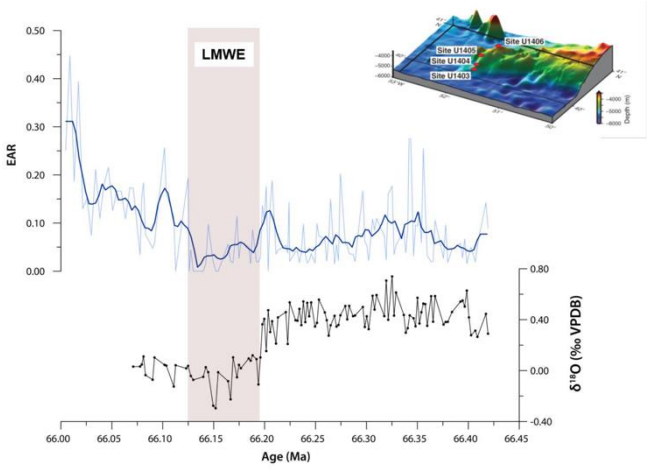

Figure 1: Correlation of the echinoid spine mass accumulation rate (EAR) with the benthic $\delta^{18}O$ curve as a bottom water temperature proxy across the Latest Maastrichtian Warming Event (LMWE).

For 113 samples (Site U1403B) we calculated the echinoid mass accumulation rate (EAR) across the Deccan volcanism-induced Latest Maastrichtian Warming Event (LMWE), well documented for the locality (Hull et al. 2020) and here shown by a benthic $\delta^{18}O$ curve (Fig. 1). EAR was calculated analogue to the benthic foraminifera accumulation rate:

EAR (spines/cm^{-2} kyr^{-1}) = ES/g x DBD (g/cm^3) x LSR (cm/kyr)

(ES: echinoid spines, DBD: dry bulk density, LSR: Linear sedimentation rate).

After values around 0.15, a decrease of echinoid biomass to values close to zero in the main phase of the LMWE occurs, followed by a rapid recovery

with values up to 0.30. The main warming pulse is also associated with a decrease of spine size. We cannot see any loss of morphological inventory across the LMWE.

Maastrichtian to early Paleocene samples from Site U1407C show a complete loss of Maastrichtian spine morphotypes paired with a decrease of spine size across the K/Pg boundary ("Lilliput Effect"). The post-event recovery in the form of increasing spine disparity and size through the lower Paleocene took at least 4 myr. The observations are in general accordance with the faunal/floral data compilation of Hull et al. (2020) for the K/Pg boundary interval. The long duration of the recovery phase could indicate *in-situ* evolution of deep-sea echinoids rather than a post-event onshore-offshore migration of shelf taxa into the deep-sea.

IODP

Challenges of recognizing a latest Eocene to early Oligocene magnetostratigraphy at IODP Site U1553

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In January 2020, International Ocean Discovery Program Expedition 378 recovered a continuously cored multiple-hole Paleogene sedimentary section (Site U1553) from southern Campbell Plateau. This sedimentary record successfully replicated that from DSDP Site 277 drilled in 1973, which has been a classic high-latitude Paleogene paleoceanographic site in the South Pacific. The geomagnetic polarity time scale of the latest Eocene to early Oligocene is characterized by reversed-polarity dominated patterns, facilitating the application of magnetostratigraphy. However, a continuous and valid magnetostratigraphy has never been established for DSDP Site 277, partly due to the by-then less advanced drilling techniques and partly because the sediments recovered are very weakly magnetized. IODP Site U1553 thus takes the challenge to identify magnetic reversals at higher quality and further a convincing polarity time scale, allowing paleoenvironmental and paleoclimatic studies to be conducted in a more robust time frame.

Here we report on the preliminary paleomagnetic results from 5 to 260 m CCSF (composite depth below seafloor). About 630 paleomagnetic samples were subject to thermal and alternating field demagnetization methods. Four pairs of normal and reversed polarity zones were clearly identified for the upper 175 meters, after which depth the magnetizations approached instrument noise level and turned inexplicable. Microscopic results reveal the wide existence of magnetic iron sulfides. We thus hypothesize that extensive sulphate reduction has resulted in the removal of remanence-bearing mineral, leading to a complication of interpreting the magnetic data. Cycle analysis of the XRF Ba/Sr data seems to place the E-O boundary at around 200 m CCSF, an eccentricity minimum, which coincides with post-cruise calcareous nannofossil study that constrains the E-O boundary interval to U1553B-22X-3 (~200 m CCSF; pers. comm. Prof. Isabella Raffi). Further studies of magnetic mineralogy will take place in cooperation with geochemical analysis.

ICDP

Disseminated sulfides in the crust-mantle transition zone in Oman ophiolite (OmanDP Holes CM1A and CM2B): Implications for mantle to crust metal flux

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A consensus exists that highly siderophile elements (HSEs), i.e., PGE, Re, and Au, are fluxed from the Earth's mantle to crust either in sulfide droplets or as metal-O, metal-S or metal-semimetal complexes dissolved in basaltic melts.

Phase 2 of the Oman Drilling Project (OmanDP) successfully diamond-cored the dunite-dominated crust to mantle transition zone of Oman ophiolite at two holes CM1A (400 m) and CM2B (300 m). These boreholes represent a complete section of the crust-mantle boundary at a fossil fast-spreading ridge, which promotes the study of refertilization processes in this interactive zone.

Available information indicates that dunite in the transition zone, although variably serpentinized, has geochemical features suggestive of extensive melt-rock reaction. Reported whole-rock $^{187}Os/^{188}Os$ values for dunite from the Wadi Tayin massif are similar to the MORB values, whereas mantle harzburgite has Os isotope composition overlapping the range of abyssal peridotite. Metal transport from the mantle to crust would lead to transition zone rocks enriched in incompatible HSEs and radiogenic Os relative to the mantle peridotites. Pentlandite, pyrrhotite, chalcopyrite, and rare monosulfide solid solution and high-temperature pentlandite-chalcopyrite intergrowths occur as ubiquitous inclusions in the transition zone rocks (mainly dunite). In the serpentinized rocks, pentlandite is replaced by millerite, heazlewoodite, polydymite, and awaruite. Our ongoing study attempts to collect in situ trace and ultra-trace element composition and Os isotopic analysis of sulfide inclusions in the different stratigraphic parts of this transition zone to provide detailed insights into the magmatic processes triggered metal fluxes in the oceanic crust.

Keywords: Oman ophiolite, mantle-crust transition zone, dunite, sulfide inclusions, trace element composition, Os isotope systematics.

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